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Benefits and Savings from Softened Water For Municipal Supply

By H. M. Olson

THIS review has been assembled for the express purpose of presenting information concerning softened water for municipal uses in such a manner as to evaluate all the savings resulting from softening. The papers reviewed for this article discuss various kinds of savings, but none has attempted to gather them all together in one place.

Two or three decades ago the average home was not equipped with the plumbing and fixtures now so common. Water heating devices were not generally used; and hot water or steam furnaces were found only in the most expensive residences. The general uses of these conveniences in recent years and the difficulties connected with maintaining them where hard water is used are reasons for the increasing demand for a soft public water supply.

W. D. Collins, in 1932, made a study of the water supplies of over 600 cities in the United States. The number of persons served by municipal water supplies of varying degrees of hardness was as shown

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A paper presented at the Central States Section meeting at Wheeling, West Virginia, August 19, 1938, by H. M. Olson, Ohio Salt Company, Wadsworth, Ohio.

in table 1. It should be noted that the list of cities studied represents about five per cent only of the total number of water supplies but the population served by these supplies is 82 per cent of the total urban population of the United States in 1930.

Leverin, in 1938, published a study of hardness of water supplies in Canada. The distribution of the population served, in terms of various degrees of hardness, is as shown in table 2. Leverin published a map showing the geographic distribution of hardness in Canadian water supplies (see references at end of paper).

TABLE 1

Varying Hardness and Population Served in U. S. in 1932

RANGE OF HARDNESS	POPULATION IN THOUSANDS	PER CENT OF TOTAL
parts per million		
1-60	20,372	29.5
61-120	18,536	26.9
121-180	10,579	15.3
More than 180	7,209	10.4
	56,696	82.1

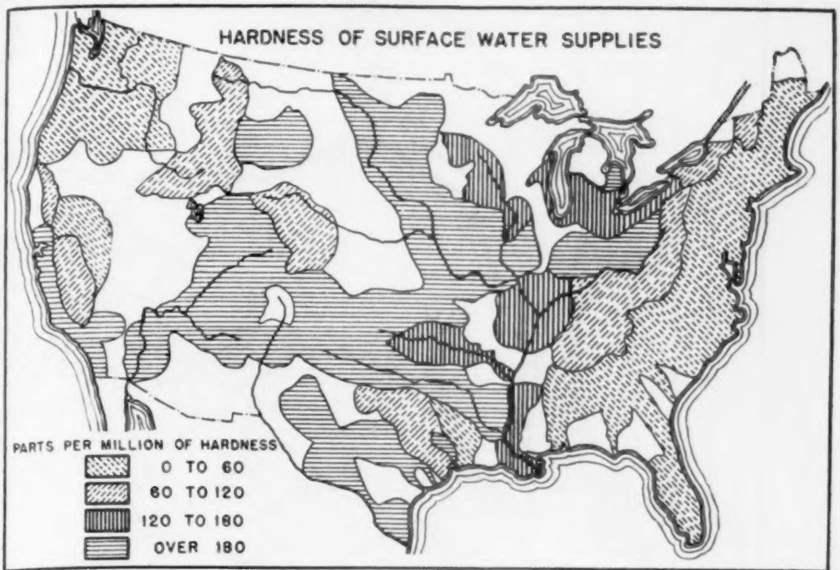
TABLE 2

Varying Hardness and Population Served in Canada in 1938

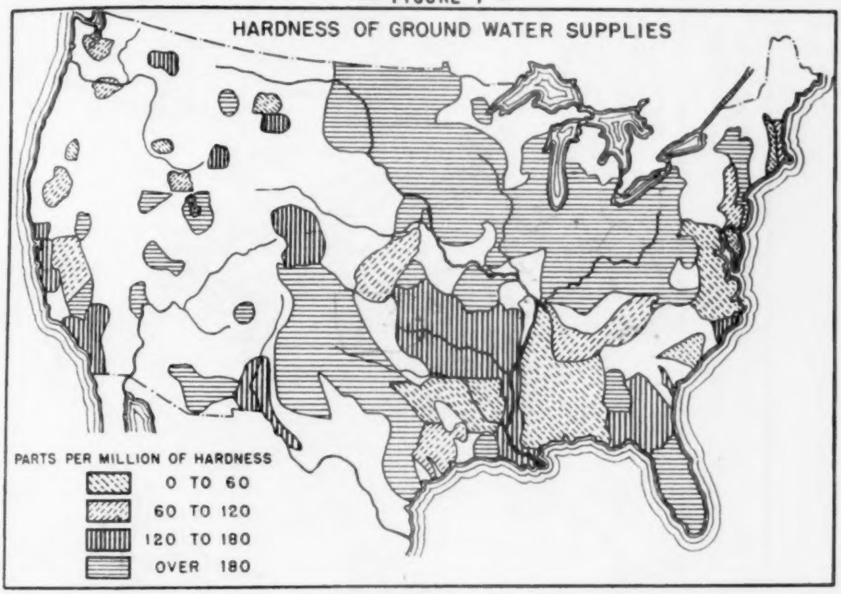
RANGE OF HARDNESS	POPULATION IN THOUSANDS	PER CENT OF TOTAL
parts per million		
1-60	907.9	16.3
61-120	1,458.7	26.2
121-180	1,057.2	19.0
181+	361.3	6.5
	3,785.1	68.0

As a part of this paper, there are reproduced, by permission, from the Report of the Water Planning Committee (1934) of the National Resources Board two maps of the United States. (See figs. 1 and 2.) One shows the geographic distribution of hardness in the surface waters of the U. S. The other shows the same information concerning ground waters.

There has been prepared especially for this paper a map of the five densely populated middle western states (Ohio, Indiana, Illinois,



— FIGURE 1 —



— FIGURE 2 —

Fig. 1. Geographic Distribution of Hardness in Surface Waters of the United States

Fig. 2. Geographic Distribution of Hardness in Ground Waters of the United States


LAKE SUPERIOR
LAKE HURON
LAKE MICHIGAN
MICHIGAN
WISCONSIN
LAKE ERIE

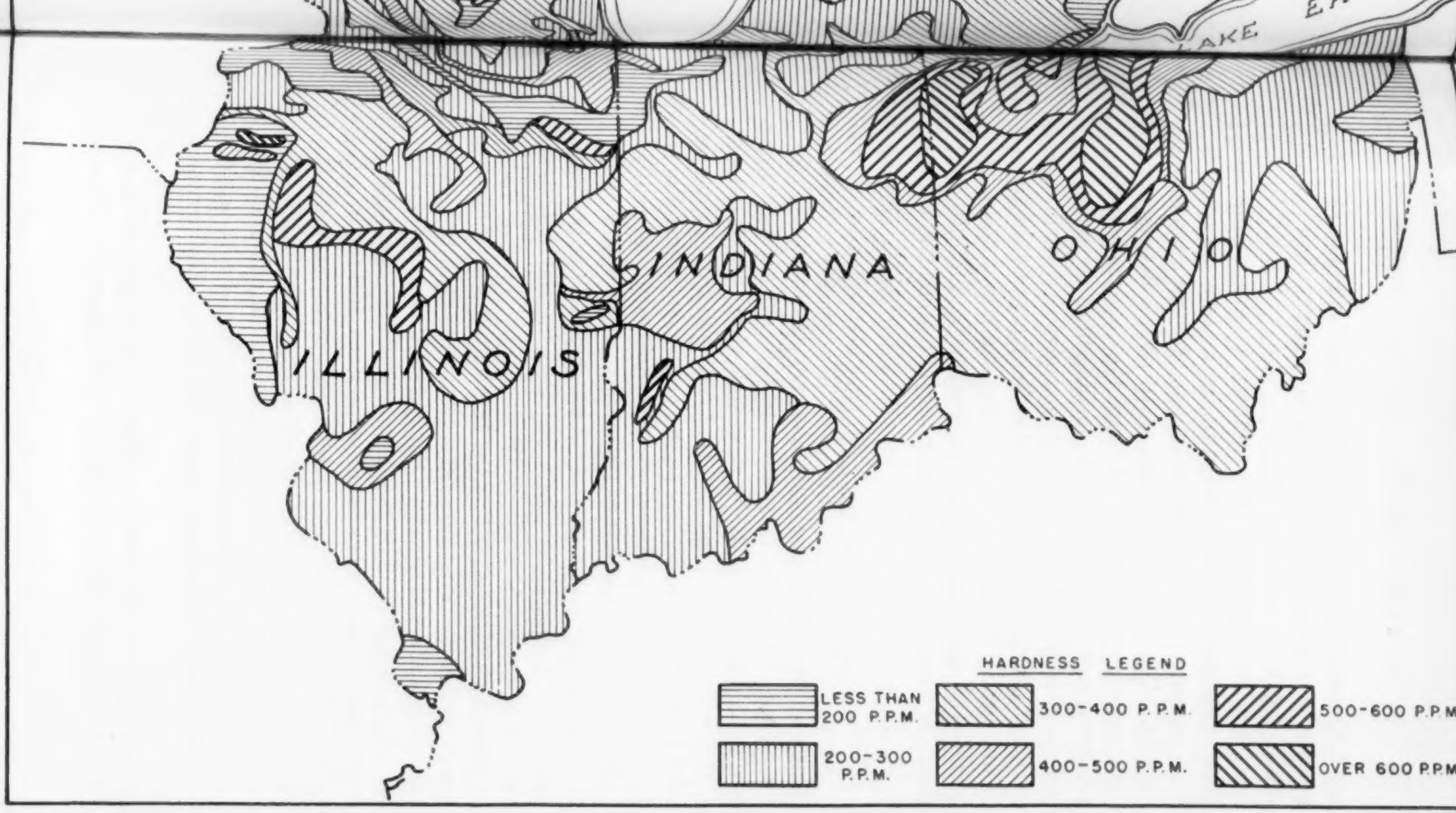


Fig. 3. Hardness of Available Ground Water in Five Middle Western States. Contours of Ohio furnished by W. H. Knox, Assistant Engineer, Ohio State Department of Health, contours for other states from data published by respective state departments of health.

Michigan, and Wisconsin) in which states the available ground water sources generally have a hardness above 125 parts per million. This map is shown as fig. 3.

Only during the last ten years of a century of availability has softening been extended to municipal supplies in any appreciable degree. Even so, only a very small percentage of water plants now employ softening. Why have these millions of people been content to use hard water these many years? Perhaps the only true explanation is found in the fact that these people, lacking in experience with water other than hard waters, are as yet ignorant of the advantages of softened water. Many still believe that softening ruins the taste, or the healthfulness. Whether or not a city shall undertake the softening of its water supply requires considerable thought, although the enthusiasm of consumers after a softener is installed is almost unanimous.

Earliest Plants Were English

The lime process for the removal of temporary hardness was patented by Dr. Clark of England in 1841, with the earliest discovery being credited to Cavendish in 1766. A short time after Clark's patent was issued, Porter brought out the fact that soda ash would remove the permanent hardness of a water. The two earliest softening plants for an entire city supply were installed at Canterbury and Southampton, England. The latter built in 1888, reduced 18° (Clark scale) water to 6° and softened approximately 2,400,000 gallons per day. The first chemical precipitation plant installed on the American continents was at Winnipeg, Canada, in 1901.

Although Allan Hazen (1904) before the International Engineering Congress stated as follows: "No important municipal softening plant is now in use in the U. S. A.," Oberlin, Ohio, was installing a chemical precipitation plant in 1903. The plant was placed in operation in 1905, the forerunner of many more in the same state, and the foundation of approximately 400 plants now installed throughout the United States. St. Louis, Missouri, in 1904, was introducing lime softening, which has been carried on in some form or other at that place ever since. Columbus, Ohio, 1908, soon followed with a large plant of 30 million gallons per day capacity, later on in 1923 increased to 54 m.g.d.

The largest plant of the chemical precipitation type for continuous year-around operation now being installed is at Minneapolis, Minne-

sota. It will have a maximum capacity of 120 m.g.d. (60 m.g.d. demand) on Mississippi River water. Twelve 84-foot diameter Spaulding Precipitators are being installed. The plant will be ready for use late in 1939.

Cincinnati, Ohio, has a plant of the chemical precipitation type that is used only when the hardness of the river supply exceeds a certain amount. The capacity of the plant as now installed is 160 m.g.d. with the average demand about 75 m.g.d. The river water hardness averaged 131 p.p.m. in 1930—a drought year (230 high and 80 low). In 1931 it averaged 119 p.p.m. hardness (184 high and 60 low). It is intended to deliver water to the city with not more than 85 p.p.m. hardness.

It is now definitely decided to use the lime-zeolite process at the proposed new plant for the Metropolitan Water District of Southern California. The water to be softened contains 305 p.p.m. of hardness, 145 p.p.m. carbonate and 165 p.p.m. non-carbonate hardness. The carbonate hardness will be reduced by lime treatment to 30 or 35 p.p.m., then enough of the lime softened water will be passed through zeolite to bring the mixture of lime softened and zeolite softened water to the desired hardness. The initial plant capacity will be 100 m.g.d. so arranged to be extended up to 400 m.g.d.

Development of the Zeolite Process

Another widely used method of softening municipal water supplies is the zeolite process, which makes use of certain granular materials, known as zeolites. This name was first applied by Cronstedt, the Swedish geologist, in 1756, to classify a certain group of natural minerals. Thompson, in 1845, discovered that common garden soil had base adsorbing powers. Way in 1850 and 1852 published his results on the base-exchanging properties of zeolites and ascribed the base-exchanging properties of soils as due to their content of zeolites. Eichhorn, in 1858, proved that these base-exchanging reactions of the zeolites were reversible. In spite of the work of these and other experimenters, it was not until about 1906, that Robert Gans, a German chemist, applied zeolites to actual commercial use for water softening purposes. As now used, the term "zeolites" has been broadened to include all materials which have base-exchanging properties.

In the United States the first zeolite plant delivering water to city mains was placed in operation at Wyomissing, Pennsylvania,

in 1923, where soft water was obtained from a local textile plant for the municipality's use. The first plant to be used entirely for municipal uses was at Laurens, Iowa, in 1924. The first large municipal zeolite softening plant (private company) was installed in 1926 at McKees Rocks, Pennsylvania, to serve a population of approximately 75,000 people. Hardness of 14 grains was reduced approximately to 5 grains. This plant is still the largest single plant. It is now enlarged to take care of increased demands (totaling 7 m.g.d.), softening to $4\frac{3}{4}$ grains hardness in the distributed water.

Now a new type of base exchange zeolite is available for municipal supplies, namely, a carbonaceous base exchange material regenerated by means of acid in the hydrogen cycle or by means of salt (NaCl) in the sodium cycle. No plants of this type are actually installed for municipal service, but some contracts have been let. Many installations are in use in commercial plants.

Censuses Show Rapid Increase in Softening Plants

In the filter plant census compiled by the California State Board of Health in 1924, 19 cities in the United States were listed as operating softening plants, supplying a population of approximately 2,000,000. Charles P. Hoover stated in 1929 that there were approximately 110 villages and cities in the United States softening municipal supplies. M. N. Baker stated in his "History of Water Treatment" that in 1934 there were approximately 150 softening plants. The census of municipal water purification plants in the United States as of 1930–1931 (A.W.W.A.) carries a list of softening plants by states. It showed 144 plants, did not include all supplies, but did cover the larger communities. Some of these plants listed as softening were intended only as alkali or lime feeders for corrosion reduction purposes, and the supply was not primarily softened. For the purpose of showing growth of softening this list can be considered as fairly accurate, indicating a population served of approximately 4,000,000.

There is at present in the U. S. a total of 394 softening plants listed either with or without pre-treatment, of which 109 are the zeolite type, and 285 the chemical precipitation type. They supply a population of over 7,250,000. Ohio has 90 plants ($24\frac{1}{2}$ per cent of the total) and Illinois has 46 plants (12 per cent of the total). Ohio still leads, but its percentage of total plants is dropping, due to growing interest shown in other states. The above information is shown in fig. 4.

Softened water in a community is recognized as a money saver. Hard water increases cost in practically every category of water use. The best study of hard water cost to a group of communities is that made by H. W. Hudson. This work involved an actual census of soap and detergent materials purchased in hard *vs* soft water areas

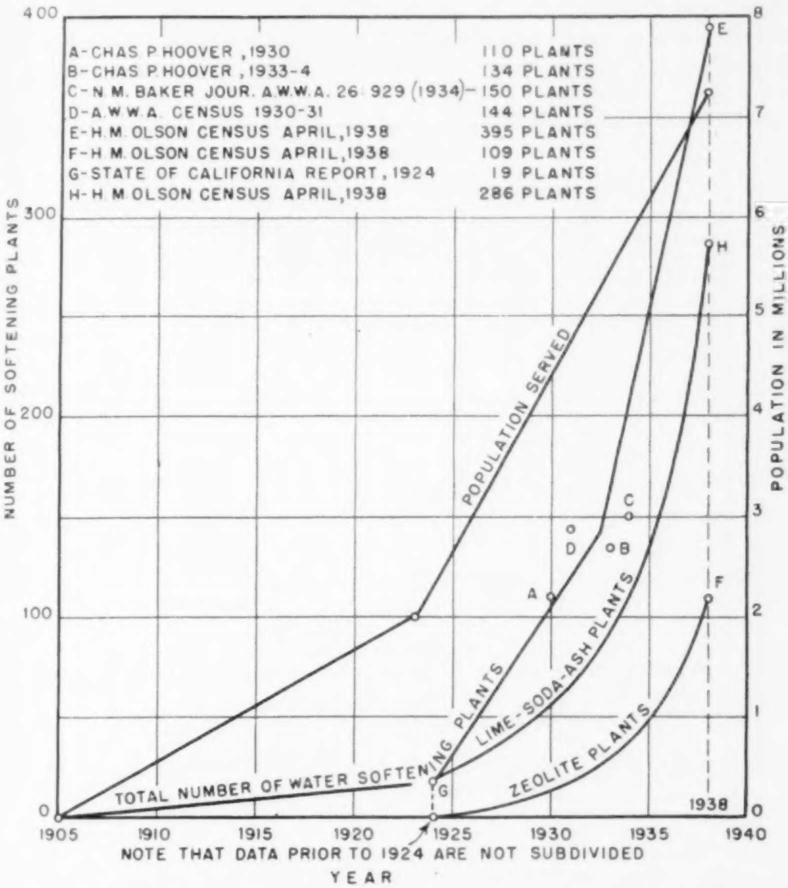


FIG. 4. Growth of Municipal Water Softening in United States, 1905-38

and the calculation of these costs upon a per capita basis. (See fig. 5.) Bloomington, Urbana and Chicago Heights, Illinois, (having hard water supplies), were compared with Superior, Wisconsin, a soft water city.

In Urbana, for example, it was shown that a municipally softened

supply would cost an added 93 cents per person per year for softening. Soap purchased to do equivalent work cost $2.18 per person per year; household water softeners would cost $7.77 per person per year; cisterns, if used for equivalent work, would cost $11.30 per person per year. Likewise in Chicago Heights, a municipally softened supply would add $2.61 per person per year to the water bill. Equivalent purchased soap costs were $3.75. Household water softeners would cost $7.93. Cisterns would cost $9.06. The cost of hard water in

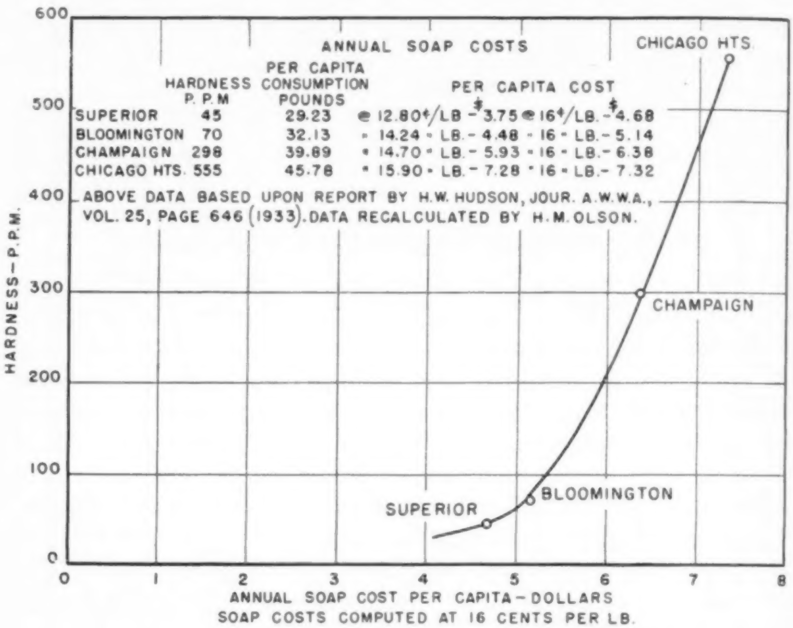


Fig. 5. Soap Cost Curve, Based upon a Recalculation of Soap Costs upon a Uniform Basis of 16 cents per lb.

terms of soap used (costing 16 cents per pound) is shown in the accompanying chart. The retail cost of various soaps and flakes considered in making up the graph is shown in table 3.

Engineering Bulletin No. 15 of the Michigan Department of Health has outlined a very good comparison of costs of softening, by means of various known methods, which bears repeating. Assuming a present supply with a hardness of 243 p.p.m., reduction to 85 p.p.m. by various softening methods will bear costs as shown in table 4.

The cost of hard water to industry is variable, depending upon the nature of the process or use made of the water. In general terms, the costs which accrue because of the use of hard water will be reduced by water softened to 85 p.p.m. in the degree shown on figure 6.

TABLE 3

Cost of Soaps and Washing Powders (1937)

	PACKAGE WEIGHT	RETAIL PRICE	COST PER LB.
	ounces	*cents*	*cents*
P. & G. Soap	9	5	9
Fels Naptha	10	5	8
Octagon	8	5	10
Large Ivory	9	11	19½
Woodbury	3	8⅓	44
Lux	3	7	37
Palmolive	3	6	32
Ivory Flakes	12½	25	32
Lux Flakes	12½	25	35
Super Suds	22	20	14½
Chipso	22	23	16½
Rinso	23½	23	15½
Silver Dust	23½	21	14
Palmolive Beads	7	11	25
Fels Naptha Chips	21	23	17½

TABLE 4

*Comparison of Costs**

	COST TO CITY OF 10,000 POPULATION PER YEAR	COST TO FAMILY OF FIVE PER YEAR
If water of 243 p.p.m. hardness is used	$29,634.00	$14.81
If private soft water systems are used	52,800.00	26.40
If the entire municipal supply is softened	24,341.00	12.17

* P. 13, Engineering Bulletin No. 15, Michigan Dept. of Health.

Many articles have been written and much research has been done to determine the amount of soap and cleaning compounds that are wasted with the use of hard waters.

Hudson as an introduction in his thesis, has put the question and answer on this matter of soap wastage so aptly that it bears repeating:

"Water differs materially in quality. For certain purposes these differences effect marked variations in utility. Where water is abundant, it is generally considered a free goods. Water, as such, without regard to quality, may be a free good. At the same time, a condition of scarcity may exist with respect to water which has certain desirable characteristics. If there is such a scarcity of water, having desirable qualities, that the supply is not sufficient to meet the demands of the public, then such water becomes of value, and will command a price. This will be true regardless of the abundance of available undesirable water. The water which lacks desirable qualities may be given these qualities through treatment by certain

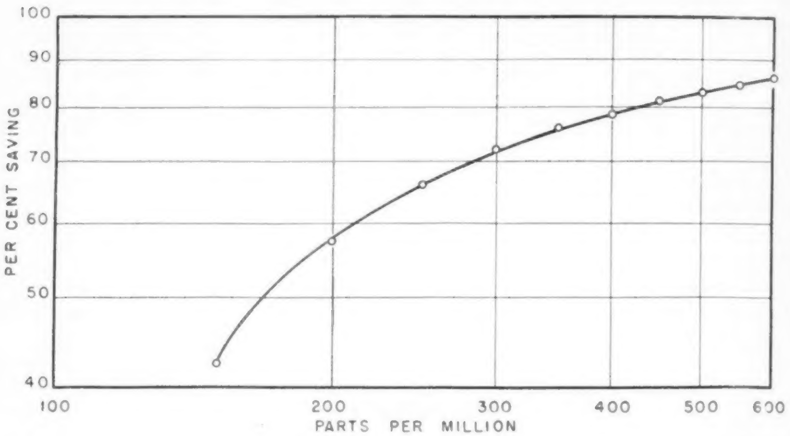


FIG. 6. Approximate Savings to Industries through Reduction in Total Hardness of Municipal Water Supply to 85 p.p.m. from Average Total Hardness in Raw Water as Shown.

chemical and physical processes. This treatment involves certain costs for which the public is willing to pay, even though the supply of undesirable water is of such abundance that it may be considered a free good.

"It appears, then, that under the conditions stated water quality has value. It is the quality that has both scarcity and utility. Water having undesirable characteristics not only lacks scarcity, but also lacks a certain degree of utility. It may be useful for certain purposes, but not for the wide variety of purposes demanded of a public water supply."

Reference to Census of Manufacturers (1929) and 15th Census of Population (1930) indicates that the average per capita soap consumption for the whole United States is 24.41 pounds of soap per annum. This amounts to 122 pounds per annum per family of five people, and with soap at 12 cents per pound the cost is $14.64. However, from a study made on prices of soaps and the tendency of the housewife to use better quality and higher priced chips and flakes, and averaging with low-priced industrial soaps (for commercial use) the cost should be on a basis of approximately 16 cents per pound. At 16 cents per pound, the average per capita soap cost is $19.52.

Soap Savings to Cities Computed

Hoover in a recent report to the City of Madison, Wisconsin, using the old figures, states soap saving should be approximately $169,000 per annum on an average 8 m.g.d. consumption with the hardness reduced from 300 p.p.m. to 85 p.p.m. If the figure of $150.00 per p.p.m. over 10 p.p.m. per m.g.d. (Shaw and Chase) is used, then this saving is $240,000 or $3.20 per person in a population of 75,000.

Selma Gottlieb states that 232 Kansas municipalities take water from underground sources, and 57 from surface supplies. The average hardness is approximately 334 p.p.m. Using Foulks formula that 68.8 pounds of soap are required to soften to zero hardness, 1,000 gallons of water of this hardness, the annual soap waste for the Kansas municipalities under consideration amounts to over 1,100 tons and with soap at 10 cents per pound, a cost of $3,531-200. This represents a loss of 25 pounds of soap per capita per year.

Wellsburg, West Virginia, (6,200 population), softened the water supply from 13 grains per gal. to 6 grains per gal. A survey made shortly after the plant was installed showed a saving of 85 per cent on soap and cleaning compounds, or approximately $10,000 per year.

A grocer at New Philadelphia, Ohio, after water of a hardness of 22 grains had been softened to $4\frac{1}{2}$ grains, reported a drop of 70 per cent in soap and cleaning compound sales.

An interesting tabulation (table 5) is found in an official laundry bulletin showing the soap savings that can be expected in power laundry operations. It states that, generally speaking, one grain of calcium carbonate hardness per gallon will destroy approximately $1\frac{1}{2}$ pounds of neutral soap for every 1,000 gallons used for suds.

Based on the formula proposed by Prof. Foulk of Ohio State University, on the assumption that "The amount of soap required to

reduce the hardness of 1,000 gallons of water one p.p.m. is 0.2 of a pound, therefore, 2 plus 0.2H = pounds of soap consumed per 1,000 gallons, with H the total hardness in p.p.m." The savings in family soap costs may be estimated as in table 6.

TABLE 5

*Costs of Soap for Various Hardness**

GRAINS OF HARDNESS	POUNDS OF NEUTRAL SOAP CONSUMED PER 1,000 GALLONS WATER	COST OF SOAP AT 12¢ PER LB.
1	1.5	$0.18
2	3.0	0.36
3	4.5	0.54
4	6.0	0.72
5	7.5	0.90
7.5	11.2	1.35
10.0	15.0	1.80

* P. 18, Official Bulletin, Laundry Owners National Assn. and the American Inst. of Laundering, Inc.

TABLE 6

Savings in Soap Costs for Family of Five by Softening Varying Hardness of Water to 85 p.p.m.

NATURAL WATER HARDNESS P.P.M. $CaCO_3$	GR./GAL.	POUNDS SOAP SAVED PER YEAR	SAVING WITH VARIOUS COSTS		
			12¢/lb.	14¢/lb.	16¢/lb.
150	8.76	24	$2.88	$3.36	$3.84
200	11.68	42	5.04	5.88	6.72
250	14.6	60	7.20	8.40	9.60
300	17.52	78	9.36	10.92	12.48
350	20.44	96	11.52	13.44	15.36
400	23.27	114	13.68	15.96	18.24
450	26.28	132	15.84	18.48	21.12
500	29.2	151	18.12	21.14	24.16
550	32.12	169	20.28	23.66	27.04
600	35.00	187	22.44	26.18	29.92

From results of the studies made by Hudson on soap consumption in several cities of the middle west an equation was formulated to show the degree of hardness necessary in any particular water supply

in order that the economy in soap obtainable by the use of soft water would pay for the cost of softening. The formula is:

$$X = \frac{C - 75D + 75F}{F - D}$$

Where X = Hardness of water supply in p.p.m. the softening of which will be paid for in soap economy alone.

F = Soap waste per capita per year per p.p.m. hardness.

75 = Demonstrated attainable hardness of water in p.p.m. from municipal water softening plants.

C = Capital overhead charges, including superintendence, per capita per year.

D = Cost of chemicals per capita per year per p.p.m. hardness.

F, D and C either dollars or cents, use same units for all items.

List of Possible Savings

Savings in Life of Linens and Clothing. In the washing of fabrics in hard water with soaps, the magnesium and calcium replace the sodium in the soap, and the resultant compound is an insoluble rancid calcium plus magnesium soap, usually referred to as a curd. This sticky matter adheres to the fibre of the fabric, and in time solidifies and tenders the fabric. Actual records of linen replacements in institutions, hospitals, and hotels show from 20 per cent to 50 per cent increase in life of fabrics where soft water is used in laundering. It is also known that fabrics stay brighter when washed in softened water. In some of the textile industries, especially in the making of rayon from wood pulp, it is essential that all hardness be removed since calcium and magnesium interfere with the processes of manufacture.

Home Laundering, Life of Linens. C. Maxwell Stanley states, "If we assume that the per capita cost of washable linens and clothes is $10.00 per year, we may assume the life to be increased 10 per cent due to improved laundry conditions, resulting from soft water. This means an annual saving of $1.00 per capita."

An analysis of one household of five adults and two children shows the cost of all washable fabrics to be approximately $280 or $40 per person. The average life is not more than $2\frac{1}{2}$ years, or $16 per year

replacement cost. (See table 7.) It would thus seem that a figure of $2 per capita is a conservative estimate of the savings which would accrue if soft water is available for washing fabrics. In institutions actual figures show savings of from 40 to 75 per cent on soaps and powders and increased life of fabrics from 20 to 50 per cent, due to

TABLE 7

Washable Fabric Costs for Family of 5 Adults

(Two Men, Three Women, and Two Children 4 and 5 years old)

	ITEMIZED COST	AVERAGE LIFE	TOTAL COST
1. Bath towels	36 @ 60¢ ave.	5 yrs.	$21.60
2. Dish towels	12 @ 25¢ "	2 yrs.	3.00
3. Hand towels	24 @ 20¢ "	2 yrs.	4.80
4. Sheets (adults)	5 @ $1.75	6 yrs.	8.75
5. Pillow cases	7 @ 50¢	6 yrs.	3.50
6. Sheets (children)	8 @ $1.00	5 yrs.	8.00
7. Pillow cases	4 @ 25¢	5 yrs.	1.00
8. Tablecloths (small)	5 @ $1.50	2 yrs.	7.50
9. Tablecloths (large)	2 @ $6.00	6 yrs.	12.00
10. Men's underwear	8 @ $1.50	2 yrs.	12.00
11. Ladies' lingerie	6 @ $2.00	½ yr.	12.00
12. Children's undergarments	6 @ $1.75	2 yrs.	10.50
13. Men's socks	14 @ 50¢	2 yrs.	7.00
14. Napkins	48 @ 50¢ & 15¢	3 yrs.	24.00
15. Washcloths	36 @ 10¢	2 yrs.	3.60
16. Dishcloths	4 @ 10¢	¼ yr.	.40
17. Scrubcloths	4 @ 10¢	⅛ yr.	.40
18. Handkerchiefs	100 @ 5¢ to 20¢	2 yrs.	15.00
19. Ladies' slips	6 @ $2.00	1 yr.	12.00
20. Children's sox	12 @ 35¢	½ yr.	4.20
21. Women's hosiery	18 @ $1.25	¼ yr.	22.50
22. Shirts	12 @ $2.50	2 yrs.	30.00
23. Children's dresses	16 @ $1.25	2 yrs.	20.00
24. House dresses	4 @ $2.00	2 yrs.	8.00
25. Misc., doilies, curtains, mats, etc.			28.25
Total			280.00

soft water, so it is fair to state that the increase due to improved laundering conditions due to softened water might reach 20 per cent or $3.20 per person per year.

Pauline Snyder stated that half again as much time was needed to launder clothes in the unsoftened water as with softened water; also, that in unsoftened water heavily soiled pieces had to be rewashed,

that all clothes had to be rerinsed, and that the general appearance of the clothes was unsatisfactory.

Cleaning Porcelain Dishes, Glassware, etc. Dishes and glassware can be more easily cleaned if soft water is available. Automatic dish washers are difficult to use in hard water areas. Porcelain fixtures and finished woodwork are cleaned more easily with soft water.

Wear and Tear on Cooking Utensils. No authentic data on this item have been published, nor could the leading cooking utensil manufacturers (both aluminum and granite ware) give any information on the effect of hard water on utensils. It is safe to assume from what we all know about cooking operations that the deposit of scale from hard water demands more violent cleaning methods than where no scale is deposited, and also that longer cooking (boiling) periods are required with hard water than with soft water. Private comparisons by staff members of one of the leading water softener manufacturers indicate that there was approximately a 20 per cent increase in the life of cooking utensils after softening the water.

Effect upon Vegetables. It has long been known that vegetables are toughened by cooking them in hard water. The lime that deposits scale in a tea kettle is taken up by vegetables in cooking, making them tough. Soft water makes for uniformity of products as regards tenderness, taste and color.

Elimination of Cost of Household Softeners. Well over 250,000 domestic softeners, both manual and automatic, are in use in the United States. More and more are being installed each year, perhaps at the rate of 7,000 to 8,000 per year, at the present time, showing the actual desire for soft water in household operations. The cost of this equipment depends on hardness of water supply, size of home, number of people served, etc.

The average softener installed in a city which has available a water supply of 20 grains hardness, will cost somewhere around $125 to $150 for a family of five people. Where a five grain (85 p.p.m.) water is available, through municipal softening, it is less easy to sell softeners to domestic users.

Savings on Salt in Household Softeners. In a large number of city homes, domestic softeners have been installed by the owners either to do away with a bad cistern condition, or to be sure that they have clean soft water. In some of the larger cities that have hard water supplies, large savings can be made if the owners of softeners still use their softeners after municipal softening is undertaken.

In Madison, Wisconsin, water having a 17.5 grain average hardness

is supplied to 75,000 population, where approximately 4,500 domestic softeners are in use at the present time, figuring five persons per family. This is about one third of the population. If these softeners are at present properly regenerated on the average of once per week, it can be seen that when a five-grain water becomes available the regenerations will come approximately only once per month. This is

TABLE 8

Pounds of Salt Required per 1,000 Gallons of Hard Water, to Produce 5 Grain per Gallon (85 p.p.m.) Effluent

HARDNESS OF RAW WATER		LB. SALT PER 1,000 GAL.
Gr./gal.	p.p.m.	
7	120	.70
8	137	1.05
9	154	1.40
10	171	1.75
11	189	2.10
12	206	2.45
13	223	2.80
14	240	3.15
15	257	3.50
16	274	3.85
17	291	4.20
18	309	4.55
19	326	4.90
20	343	5.25
22	377	5.95
24	411	6.65
26	446	7.35
28	480	8.05
30	514	8.75

Note: The above data are based on a salt consumption of 0.35 lb. per 1,000 grains of hardness removed, as commonly used in municipal water softening practice. They should not be applied in studies of cost of operating domestic water softeners.

a saving of 75 per cent in domestic softener salt consumption. If we assume in the case of Madison that 500 pounds of salt are used per annum per installation (at a cost of \$1.00 per cwt.), then the savings will amount to \$18,750 per annum for the community as a whole.

Savings on Backwash Water on Household Softeners. This saving

can only be of any sizable amount in such communities as have a large number of domestic softeners. Such cities as Dayton, Ohio, Indianapolis, Indiana and Madison, Wisconsin, fall in this category. For instance, Madison, a city of 75,000 has approximately 4,500 domestic softeners operating on water having a hardness of $17\frac{1}{2}$ grains per gallon, with most of the units softening the water for hot water use only. Figuring these softeners as averaging 15 inches in diameter and regenerated once per week with hard water, but once every three weeks with a $4\frac{1}{2}$ grain soft water, water users could save approximately three-fourths of the backwash water now used. With each regeneration (assuming the softeners all to be downflow) they would use approximately 40 gallons of water and save 1,440 gallons each per year, if the softer water was available.

Elimination of Cisterns. C. Maxwell Stanley, states that cisterns cost, on the average, $150 each with pumps, pressure tank and extra piping. In a statement of the Board of Water & Electric Light Commissioners of Lansing, Michigan, this statement is made, "The average cost of a 100-barrel cistern with duplicate soft water plumbing is approximately $300. Allowing 6 per cent interest on the investment with nothing for depreciation and maintenance, the cost would be $18 per year or about eight times what would be the added cost for a continuous supply of soft water under pressure. The cistern water will not be safe to use for all purposes, will be limited in amount, frequently will have an odor and will usually be colored."

Where a consumer already has a cistern with equipment, the Lansing report goes on to state, "Cisterns are dirt catchers and serve as receptacles for filth washed from the roof. They require frequent cleanings in this vicinity at a cost of from $4 to $5 per cleaning. If a cistern is cleaned only once in two or three years, the cost of cleaning alone is as much as the added cost to the average householder of softening the entire supply of the municipal plant. Even though a consumer is now using a cistern he will save from $1 to $2 per year by having the city soften the entire supply. He will also have an abundant supply of pure, clean water, which is not possible with a cistern."

In New Bremen, Ohio, (a community of 1,800 with approximately 400 services), almost everyone had a cistern in 1929 when the new softening plant was installed. With a continuous nine-year record of clean, clear, soft dependable water the number of actual cisterns has been reduced to ten, with some of these acting only as standbys.

Elimination of Duplicate Plumbing. Where cisterns are in use, duplicate plumbing with a motor to drive the pump has to be installed at an added cost where hard water is the only municipal supply available. Soft water from the city tap eliminates the initial installation of this piping and removes the constant cost of electricity to run the system and the cost of maintenance. The Water Commission of Neenah, Wisconsin, estimates the savings on electricity for water-pump power at 35 to 50 cents per family per annum due to the availability of softened tap water.

Repairs to Plumbing, Water Tanks, Heaters and Heater Coils. This item of cost is hard to determine, as different types of solids will deposit in pipe lines, tanks, etc. at different rates. A careful study of this must be made in various localities. It remains as a reasonable fact, however, that if proper piping and tanks, etc., are installed on low hardness water in proper chemical balance, repairs will be at a minimum and installations should last many years. Plumbing repair can be kept at a minimum or entirely eliminated by installation of proper materials and by care on the part of the householder, if the water company or department furnishes a properly chemically balanced and softened water supply.

Repairs to Gas Heaters, etc. A great source of expense to the householder in hard-water areas is that of repairing, cleaning and replacing gas heater coils of various types. Bulletin No. 15 of the Michigan State Department of Health states that the average cost of repairs is approximately $4 per year. *House and Garden* in February, 1935 stated, "In Madison, Wisconsin, few houses costing more than $4,000 are now constructed without installation of a water softener. The gas company there has found that the average cost of water heater cleaning service is $5.20 a year when the natural water is used, as against $1.25 a year when the water is softened."

Fuel Loss Heating Water in the Home. It is an established fact in boiler operations that better fuel efficiency and lower cost of operation are obtained with softened water, and that with soft water chemically balanced good thermal efficiency is obtained as far as a particular water condition is concerned. Although no extensive research work has been conducted, and neither the manufacturers of gas water-heating equipment nor The American Gas Association has any data on savings of fuel (gas) with varying hardness of water, it is apparent that considerable savings can be and are made when softened water is used.

Considerable research has been conducted on boilers where different thicknesses (and chemical structure) of scale have retarded heat flow to show the losses. It is reasonable to expect that with the same thickness of scale in a hot-water heater as in a boiler that the same per cent loss will be obtained. However, we know that, with scale up to $\frac{1}{4}$ inch or more in thickness and with the rapid flow of gas heat over the contact surfaces, this loss is far greater. So it would be safe to state that with chemically balanced tap waters of 4 to 5 grains hardness, on water originally up to 15 grains hardness the saving might be 25 per cent, and on waters up to 35 grains, the saving might be 50 per cent.

In order that an estimate of savings of fuel (gas) can be made several assumptions have been made. For example, the amount of hot water used varies considerably in different types of households, but the approximate amount used in one family of five adults and two children is 3,000 to 4,000 gallons per month. Figuring on a 50°F. average cold water and 130° average hot water with gas at 60 cents per 1,000 cubic feet (natural) and $33\frac{1}{3}$ per cent savings in fuel if soft water is used, we develop approximately \$1.50 savings per person a year.

Figuring possible savings and comparing amounts of water consumed against that reported in the thesis of Pauline Snyder, we arrive at the following:

1 cubic foot natural gas = 1,140 B.t.u. (500 B.t.u. available).

Cold water average—50°F.

Heated water average—130°F.

Gas at 60 cents per 1,000 cubic feet (500 B.t.u. Effective Use).

Then from table 9, 1,660 x 8.33# is 13,827 raised 80°F. = 1,106,000 B.t.u. required.

And 1,106,000 divided by 500 = 2,200 cubic feet at 60 cents = \$1.32 per month for heating water.

If we assume 25 per cent savings on 10 grain water, the savings therefore are 25 per cent of \$1.32 or 33 cents per month, \$3.96 per year or 57 cents per person per year.

Fuel Loss Heating Water in Industry. In a great number of commercial and industrial plants, hot water of varying temperature is required, both for processing, cleaning, and for boiler feed water. This may be heated by means of closed-type heaters employing steam coils and large-type gas heaters. When hard water is used, scale forms on the outside of the tubes, similar to that formed in a fire-

tube boiler. In most cases the deposit is due only to the temporary hardness in the water, which precipitates out approximately at 160°F. This, as a rule, forms a softer type scale. On the other hand other characteristics of the water may tend to form a harder scale. The savings resulting from use of softer water in industry in general are shown in fig. 6 (p. 618).

Fuel Loss in Boilers. In the home the loss from scale in boilers or heating equipment is negligible, as most systems employing water as a heating element have return systems. In industry, as well as in various types of institutions, hotels and hospitals, considerable trouble is experienced from fuel losses, repairs, etc., due to formation of scale.

The U. S. Bureau of Mines shows variable losses due to thickness of scale and its composition, but it is generally accepted as a conservative figure on heat loss that $\frac{1}{16}$ inch of a medium hard scale will show a loss of approximately 16 per cent in fuel. Of course, any given condition must be studied in itself and on its own merits, as so many items enter into any estimate on losses, in boiler water actually being evaporated, such as hardness, matter in suspension, load ratings, frequency of blow-down, and feed water treating system.

The effect of scale is very well described in Bureau of Mines Technical Paper number 218 as follows: "In many respects the effect of an increasing deposit of scale on the passage of heat through the walls of a boiler tube is very similar to the effect on the passage of water through a tube of continually decreasing bore. In the case of the water tube, the only way to get a uniform volume discharge through it in a given time, in spite of its diminishing bore, is continually to increase the pressure in the water; so in the case of the boiler tube covered with a dense scale, the only way to keep a constant flow of heat from the furnace to the boiler water is to increase the 'heat pressure' so to speak; that is, to burn more fuel."

Boiler Blow Down. In chemical precipitation methods of softening, there is a reduction of the total solids in water, the amount depending on the chemical characteristics of the raw supply and the equipment used. This is not a fact, however, in the use of base-exchange minerals where salt is used for regenerating purposes. But in these cases considerable pre-treatment is used and a very clear (or clearer) water is obtained. In the case of the chemical precipitation systems the total solids are reduced, and in the case of zeolites, a clearer water is produced. So in the operation of power

boilers or any system where a concentration of salts occurs, considerably less water (consequently less heat) is wasted in blow-down operations. In any particular case or locality, a study has to be made covering cost of fuel and other factors to determine the savings actually made.

Boiler and Softening Compounds in Industry. In a large number of boiler plants, some sort of chemical compound is used, either to soften the make-up water or to inhibit corrosion. As a rule the chemical compound is bought under some particular trade name. It is used under the supervision of some water conditioning expert, or is used under the owner's jurisdiction. Some relief is had in most cases from aggravating scale conditions, but as a rule it is a more

TABLE 9

Analysis of Family Water Consumption

	ESTIMATED TOTAL	HOUSEHOLD 5 ADULTS, 2 CHILDREN (AVERAGE CONSUMPTION), HOT WATER	SNYDER (O.S.U.) THESIS 1927 3 ADULTS, 2 CHILDREN, HOT WATER
60-20 gals. (showers)	1,200 gals.	600	580
30-10 gals. (bath tub)	300 "	150	
Dish washing—20 gal. day	600 "	400	310
Cleaning	100 "	60	18
Hand & face wash	200 "	100	230
Laundry	500 "	300	64
Misc.	100 "	50	
Total	3,000	1,660	1,212

expensive operation than the cost of softening the supply by external treatment.

Boiler and Softening Compounds in Institutions. In institutions, hospitals, hotels, restaurants, etc., where softening compounds are used in dish and glass washing operations, extra care has to be taken to clear off the haze or scum which can be almost entirely, if not altogether, eliminated by use of softer water.

Boiler Cleaning and Repairs. With the formation of scale in and on tubes and the interior of boilers, a large amount of labor and expense is entailed for cleaning, for repairs due to blistered and damaged tubes, and for other boiler parts. This cleaning may be done by various types of chemicals or by mechanical means. Plant engineers who have operated a turbine cleaner know the trouble

required to take a boiler off the line and put it back in again. Loss in fuel, water for cleaning and removing, turbines for cleaners, gaskets, etc., all are items of expense.

Elimination of Scale in Piping Systems. Piping will incrust if the water is hard. It is very common to have small pipes in houses or plants entirely clogged. These have to be taken out and replaced. Pipes as large as 6- or 8-inch with openings reduced to 1-inch or under are common under hard water conditions. This pipe clogging cuts down the flow of water in the pipe and the pressure must be increased with consequent increase in pumping costs.

Savings on Salt and Chemicals. It is natural to suppose that, where there are many domestic units in use, there are also many industries and institutions using softeners, both of the zeolite and chemical precipitation types. The same analysis of savings on salt can be used as stated above. There are large savings on chemicals where a five grain water is used in chemical precipitation types of softeners. Analyses must be made of each case, and it may be that it will be cheaper to discontinue a particular softening plant entirely or soften down further by means of a zeolite unit.

Bottled Beverages. Experience in using water for bottled beverages has shown that soft water will give a superior product free from sediment or precipitate and make a more salable and palatable product. The modern bottling plant's problems are much heavier if a hard water is used.

Industrial Process Water for Canning, Textiles, etc. Soft water for canneries is very important. Peas, etc. will absorb calcium from hard water and lower the market value of the product. The results of a study by the National Confectioners Association indicated that the most satisfactory hard and fondant candies were made with water less than 50 p.p.m. but not more than 100 p.p.m. in hardness. In paper making, especially high grade papers, hardness will interfere with proper sizing. A soft water is desirable.

In textile plants the need of soft water is being given more and more attention. Those plants which started with it for a few of their many operations have found that costs, results and salability of product demand soft water all through processing. In rayon manufacturing, waters with as low as 2 to 3 p.p.m. hardness are sought and delivered constantly for use.

Auto Radiators and Car Washing. Automobile radiator tubes, when hard water is used in them, will fill with scale and clog, thus

preventing free circulation of cooling water. In cases where the water is extremely hard, frequent cleanings are required at extra cost over that of localities having softened or soft-water supplies. In the hard water belt of Florida one of the nationally known oil companies has small-sized domestic softeners in each station for furnishing soft water for radiators. This is also the case in other localities where conditions demand removal of impurities. In car washing, the hardness will in some cases destroy the finish and in most cases will leave a streaked job, necessitating extra labor. With softened water these troubles are reduced to a minimum.

Growth of Cities. Excessively hard water retards the growth of cities. Burdick and Howson, in a study of ten Illinois cities, have shown that eight have comparatively soft water as judged by mid-western standards, whereas the other two have supplies that are excessively hard. The two hard water cities in 1880 had 26 per cent of the total population of the state and in 1920 only 10.7 per cent. It thus appears that hard water had an effect on desirability of these cities for homes and industry.

Restricted Use of Hard Water, etc. In those municipalities that have hard water, and where cisterns are in use, lower consumption of the particular municipal supply follows. Where a home owner has a softener in his home, and soft water can be had with the turning of a faucet, then the demand for that type of water increases. That is also the case where the general supply has been softened. In almost every locality where softeners have been installed to treat the city supply, steady increases have been noted in the consumption over a term of years.

The superintendent of the water works at Genoa, Ohio, where a zeolite water softener and pre-treatment equipment were installed late in 1932, gives us the following résumé of results: In 1933 there was an average of 133 services serving a population of about 465. The total amount distributed for the year was 5,500,000 gal. with a daily per capita consumption of 32.5 gal. By 1937 the average number of services for the year had increased to 259 serving a population of approximately 955. The daily per capita consumption had increased to 44.1 gallons and the total distributed for the year was 14,500,000 gallons.

At Bicknell, Indiana, where the public supply had previously been quite unsatisfactory, two months after the softened water was turned into the mains, there was an increase of 30 per cent in con-

sumers. Approximately 50 per cent increase in consumers occurred during the first year, together with a sizable increase in the per capita consumption. It has been shown in many municipalities that a substantial gain of total community demand has been experienced when soft, clean, clear water is made available.

Concentrated efforts to promote water softening have been lacking. Some systematic course needs to be followed to stimulate the public's desire for soft water. Enough data are at hand in the 394 communities now having municipal softeners to convince even the skeptical.

Ways to Encourage Municipal Softening

Burdick in 1936 stated, "The best argument for a municipal softening plant is the satisfaction that consumers show when a good plant has been installed. No town that has installed municipal softening has gone back to hard water." There have since been some interruptions in some of the plants, due to lack of funds and curtailment of expenses in operation, but not more than four or five cities have taken this backward step.

Today the public is no longer satisfied with water that is merely bacterially safe, but demands water that is clear, sparkling, low in color, palatable, reasonably soft, and non-corrosive. There are for example, at least 262 local public supplies in the state of New York whose properties are such that they could be improved by means of water softening, according to information made available by the Division of Sanitation of the State Department of Health.

In evaluating a particular city's supply to determine what savings are to be expected, it is essential to make a study of how the water is used, and how it is divided in its uses. Pedersen made a detailed study of water supplied in Marshalltown, Iowa, which can be used as a basis for an intensive study in any community. In that city 48.3 per cent of the water pumped is used for industrial purposes (including railroads), 30 per cent is used for general city sanitary purposes (fire fighting, parks, lakes and at pumping station) and 21.7 per cent for domestic purposes. This latter category includes drinking water, 1.085 per cent; flushing toilets, 9.765 per cent; cooking, 1.3 per cent; bathing and washing, 6.51 per cent; housecleaning, 0.651 per cent; laundry, 0.868 per cent, lawn sprinkling, 0.651 per cent; car washing, 0.22 per cent; and miscellaneous, 0.65 per cent.

In the case of the industrial plants, schools, hotels, power plants,

packing plants, canneries, and miscellaneous manufacturing establishments, a study must be made of the uses of water to see how hardness affects operating costs. In the domestic uses one will note that for practically all purposes a soft water is more suitable than a hard water, but that the main savings will be made in but approximately 10 per cent of the total supply pumped. In this amount of water enough savings can be made, with moderately hard water to show economy enough to pay for the installation of municipal softening equipment.

Haase in 1937 stated that, in a study made in Germany, the approximate divisions of water uses were: industry, municipal and water works, 70 per cent (maximum 81 per cent); domestic, 20 per cent; and losses, 10 per cent. Water used in an average home of four persons was divided as follows: bathing, 35 per cent; toilets, etc., 29 per cent; drinking, cooking and cleaning, 24 per cent; and laundry, 12 per cent.

Each Consumer Should Be Enlightened

Any campaign to develop support for a water softening project must not overlook the individual consumer. Information of a technical nature should be made reasonably simple and understandable. This is frequently more important than the technical reports made by consulting engineers for the city officials or the water works operators. Such a method is outlined in a paper by Shattuck commenting on the methods used in the "Successful Campaign in Neenah (Wisconsin) for Water Program Approval."

This brief statement records the fact that a citizen's committee was organized for the purpose of developing community support for a water softening plant. More than six months time was spent in the campaign. The expense was privately underwritten. An experimental softening plant was set up on the main street.

An operator was secured for this plant who was able to answer questions from passers-by in such fashion as to develop support for the project. The support of the local papers was enlisted. Talks were given to every possible group of listeners. Window displays were made. A booth was used at the Home Show. Washing demonstrations were made. Stories of the satisfaction of other cities with soft water were told at luncheon clubs and through the press. Data regarding the losses of business to the city and to the water department because of hard water were circulated.

Finally a committee of 72 (city population 9,151 in 1930) made a house to house canvas. The result was that the citizens voted 4 to 1 in favor of water softening.

Three documents issued by the cast-iron pipe industry can also be consulted when plans are being made to conduct such a campaign. These are: "Water Works for Every Town" published by the Cast Iron Pipe Research Association, "Promoting Water Works" published by the American Cast Iron Pipe Company, and "Community Advertising" published by the Cast Iron Pipe Publicity Bureau.

In conducting a campaign to develop support for the installation of a municipal water softening plant these points should be fully emphasized:

1. The greatest monetary saving is in that of soap and cleaning compounds used in commercial enterprises as well as in the home. The value can be determined in dollars and cents with direct relation to the hardness of the original water. Much has been written on this matter so that a fairly accurate prediction can be made beforehand.

2. Fuel loss in boilers and processing with hard water can be largely eliminated. This loss is in direct proportion to the hardness.

3. Savings in cost of boiler compounds can be made about in direct proportion to the hardness.

4. Boiler cleaning and repairs can be kept at a minimum with large savings resulting.

5. Scale elimination in piping systems will result in large savings on heat, maintenance, and plumbing.

6. Savings can be made on life of linens and washable clothing. This is from $1 to $2 per year per capita. An increase of 20 to 50 per cent in the life of linens can be had in institutions, hotels, and similar establishments.

7. Savings in direct proportion to hardness can be made in operation of household softeners, in use of chemicals required, and time and attention required. Maintenance will be less and life longer.

8. Savings can be made in preparation of foods, in the home, in eating places and in the food processing plant.

9. Almost every phase of home life operations is adversely affected by hard water. Savings both on original expenses and maintenance cost will accrue when softened water is available.

10. In many classes of industrial enterprises, in processing, and in production of power, large savings can be made which are in most

cases in direct proportion to the hardness. Due to the use of soft water a better product is produced, resulting in more money received for goods.

11. Industry will locate in a city with a soft water supply in preference to one with a hard supply, other conditions being equal.

12. With an abundant supply of suitable soft water at the consumer's faucet, more water will be used. Increased revenue to the plant and continued satisfaction to the consumer will develop.

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Reclamation and Re-use of Lime in Water Softening

By William W. Aultman

ONE of the major problems confronting engineers and designers of water softening plants has been the disposal of the sludge produced from the softening process. That this has not been a problem for which a solution was absolutely required long ago is due to the fortunate location of the large eastern and middle western cities, with their treatment plants adjacent to sizable waterways into which this sludge can be dumped. In some parts of the middle west and in practically all of the far west, the cities are not so favorably situated. As a consequence, in these locations unsightly and often expensive sludge lagoons must be provided or some means found for otherwise disposing of the sludge. This is the situation which The Metropolitan Water District of Southern California faces when contemplating the construction of treatment plants to soften Colorado River water.

This problem is not one of sludge disposal alone but also one which involves the waste of vast quantities of potential raw material which could supply the necessary lime for this same softening reaction. The sludge produced when water is softened by the lime or the lime-soda ash method of treatment is principally composed of calcium carbonate, which, in the form of limestone, is the same material from which the lime was originally produced. If lime can be economically reclaimed in a way to produce a satisfactory product for re-use as the softening agent, a saving will accrue from this reclamation and from a reduction in the quantity of sludge which must be disposed of as waste material.

The purpose of the water treatment investigations made by the

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A paper presented at the California Section meeting at Riverside, California, October 27, 1938, by William W. Aultman, Assistant Engineer, Metropolitan Water District of Southern California, Los Angeles, Calif.

District at Boulder City was, therefore, to find a means whereby the quantity of sludge which must be disposed of would be reduced and at the same time to find an economically feasible method of reclaiming lime from the sludge produced, which would be of a quality suitable for re-use in the treatment process. This paper has been prepared to describe the investigations which were made, some of the problems encountered, and the results obtained.

In waters containing very little or no magnesium, which are softened with lime or lime and soda ash, the problem of reclaiming the lime from the sludge and its continued re-use in the treatment process is relatively simple. The sludge pumped from the plant clarifiers may be partially unwatered by means of a vacuum filter and the cake thus produced is reburned in a rotary or multiple-hearth type of calcining furnace, the kiln product being slaked, classified to eliminate any undesirable grits and then re-used in the regular treatment process.

Direct Reburning Employed in English Plant

Insofar as can be determined, this method has not been successfully used in the United States but has been, and is, in use at the water softening plant of the Southend Waterworks Company of Langford, England (1, 2). At this plant, the magnesium content of the water is relatively low (averaging 8.3 p.p.m. as Mg) and is reduced to an average of 3.2 p.p.m. during treatment. The lime produced and re-used has shown no appreciable build-up of the undesirable magnesium and inerts, even though removing 5.1 p.p.m. of magnesium. In 1937, after eight years of operation of the recovery plant, an analysis of the lime showed it to contain only 7.5 per cent magnesium as MgO and to have an "available lime" content as CaO of 75.0 per cent. During this period, no new lime has been added to that reclaimed.

Where waters are high in magnesium, as in the case of Colorado River water which contains an average of 25 p.p.m. of magnesium as Mg, this straightforward method of lime reclamation and re-use is not satisfactory, for the magnesium content of the reburned lime will increase to such an extent that the lime will be unsuitable for use in the water softening process. The magnesium oxide contained in the lime, insofar as its action as a softening agent is concerned, is essentially so much inert material to be handled over and over again.

FIGURE 1. FLOW SHEET OF ESTABROOK PROCESS

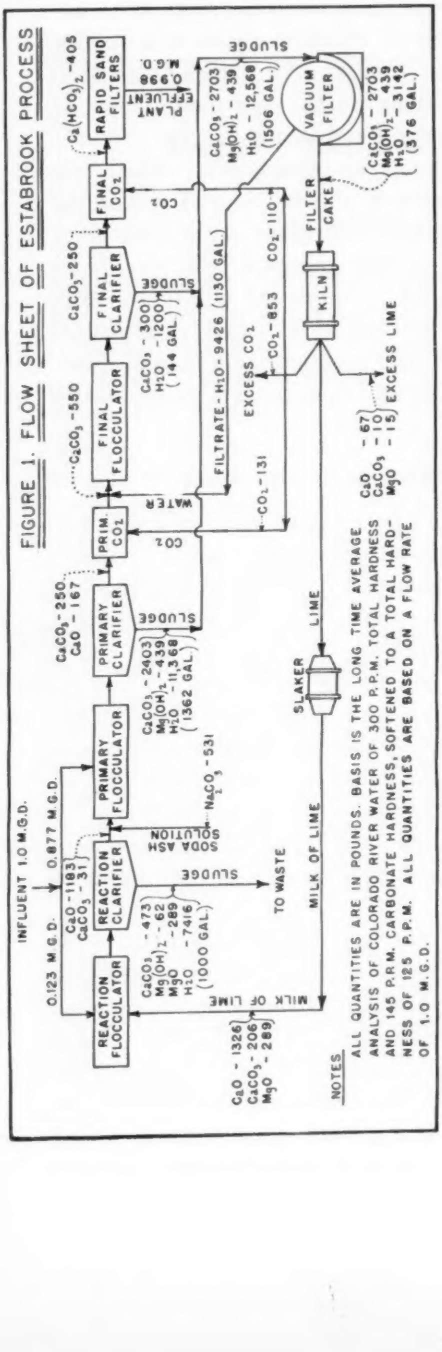
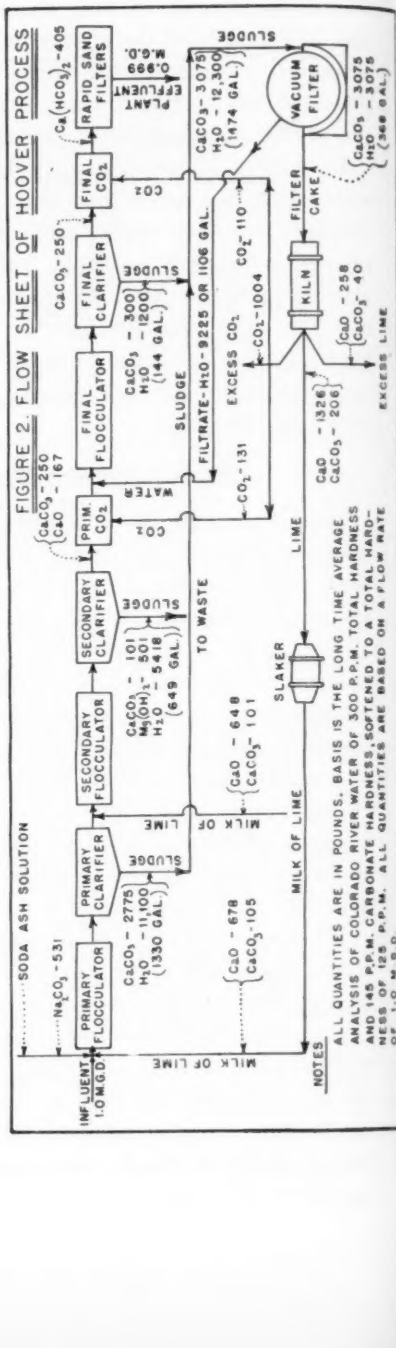


FIGURE 2. FLOW SHEET OF HOOVER PROCESS



In September, 1936, an as yet untried method was suggested to the District by the Dorr Company, which has been licensed to use the so-called Lykken-Estabrook process (11) which eliminates the build-up of the undesirable magnesium, even with continued re-use of the reclaimed lime. This process accomplishes this result by using a split treatment, adding all the lime required for softening to just sufficient water to put it into solution, settling this mixture, and then mixing this clear lime solution with the remainder of the water to be treated, together with any other chemicals which may be used. This process is most readily visualized by the flow diagram shown in fig. 1. It will be noted that the sludge produced from the small split, or reaction clarifier, contains the magnesium hydroxide from softening this small amount of water in addition to the magnesium oxide produced in the reclaimed lime from the main plant. This sludge is wasted. The sludge from the main plant, which is identical to plants of standard design, is reburned to produce lime for re-use in the treatment process. The flow diagram in fig. 1 has been worked out to show the sludge and lime production from a typical plant of 1 m.g.d. capacity treating Colorado River water. The long-time average mineral composition of Colorado River water has been used for this computation. It has been assumed that the lime has a solubility of 1.31 grams per liter. It is noted from this diagram that under the conditions presented there will be an excess of 67 pounds of lime, as CaO, produced per million gallons of water treated. Different hardness characteristics of the water will, of course, vary the percentage split required to dissolve the lime and will vary the amount of excess, or deficiency, of lime produced per cycle.

Laboratory tests of this process were made by the District. Insofar as could be determined from these tests made on a laboratory scale, the process appeared sound. It was therefore decided that further tests be made on as nearly full plant scale as possible. It is the purpose of this report to describe and discuss these further investigations.

Another process, which has recently been developed by Charles P. Hoover, prominent water purification authority of Columbus, Ohio, has been turned over to the Nichols Engineering and Research Corporation for development and promotion. This process accomplishes the same purpose of eliminating the magnesium build-up by adding just sufficient lime in the first stage to precipitate the

calcium, then adding the necessary additional lime in the second stage to precipitate the magnesium, a third stage being the same as the final clarifier of a standard plant, to precipitate the calcium carbonate formed by the addition of carbon dioxide to the caustic effluent from the secondary stage. This process is best shown by the flow diagram in fig. 2. This flow diagram has been worked out similarly to that for the Lykken-Estabrook process showing the quantity and quality of sludge which will be produced. In Mr. Hoover's process, sludge from the primary and final clarifier is used for reburning; the sludge from the secondary clarifier, containing the undesirable magnesium compounds, being wasted. It will be noted that the amount of excess reburned lime, as CaO, theoretically procurable from this process, is 258 pounds per million gallons of water treated, which is somewhat greater than that from the Estabrook process.

Because of the time available and the unsuitability of the experimental plant arrangement, the Hoover process has not been further investigated by the District.

Tests Made on Full Scale Operation

The tests were carried out with the coöperation of the U. S. Bureau of Reclamation, which allowed the supplemental equipment to be installed at the Boulder City, Nevada, water softening plant, and allowed the lime to be reclaimed from and re-used in the main plant, thus providing full-scale operation for the tests. Complete descriptions of this plant have already been published in the technical literature by Burton Lowther (3), Earl M. Kelly (4), and D. M. Forester (5, 6).

The excess lime-soda ash treatment is used at Boulder City to soften the Colorado River water. The designed capacity of the plant is 2.0 m.g.d. when operating in series, which is normal procedure. The plant contains essentially a primary and secondary unit each consisting of two 14 ft. by 14 ft. by 12 ft. mixing basins in series, equipped with Dorrco paddle mixers, which serve as both mixers and flocculators; followed by a 45 ft. square by 9 ft. 6 in. side wall depth cross-flow clarifier basin, equipped with a Dorrco traction drive mechanism. This in turn is followed by a 54 ft. by 5½ ft. by 12 ft. carbonation basin. The effluent from the secondary carbonation basin goes to four conventional gravity sand filters, each of 500,000 g.p.d. rated capacity.

To act as a receiver and storage for the sludge from the main clarifiers, a 1,000-gallon tank was installed to which the discharge from the main sludge pumps fed; the outlet from this tank being fed directly to the pick-up reservoir of the vacuum filter.

Vacuum Filter Used

Before the sludge from the main clarifiers can be fed to the calcining furnace, it must be partially dewatered. This was accomplished by means of a continuous vacuum filter. An experimental filter was procured for this use from the Oliver United Filters, Inc., which was 3 ft. in diameter with a 1-foot filtering face. This gave a total filter area of 9.4 sq.ft. With this was also included the auxiliary equipment consisting of vacuum pump, air compressor, filtrate pump, variable-speed filter drive, and necessary receivers, etc. This filter was so located that it discharged the partially dewatered filter cake directly onto the top hearth of the lime calcining furnace.

Calcining Furnace Is Multiple Hearth Type

Conventional rotary kilns have been used successfully for years in the causticizing and chemical industries where similar filter cake is fed. Recently, however, some investigations have indicated that the multiple hearth type of furnace such as the Nichols Herreshoff, the Wedge, the Evans-Klepetko, or the Skinner furnaces would give a much more uniformly burned lime at a lower fuel consumption. Consequently, a Nichols Herreshoff six-hearth, 54-in. inside diameter, so-called Laboratory Type Furnace, was purchased from the Nichols Engineering and Research Corporation, in order that information might be obtained relative to its efficiency and operation. The rated furnace capacity was only about 62.5 lb. of burned lime per hour, but in actual operation, 100 lb. per hour was closely approached, as will be shown by the later data and discussion. A detailed drawing of the furnace is shown in fig. 3.

The furnace is a vertical, brick-lined, iron or steel cylinder, having six superimposed hearths within the furnace and a top, so-called drying hearth. There is a central rotating shaft which carries radial stirring arms having blades, or rabble teeth, set at the proper angle for stirring and moving the material. The shaft and arms are air-cooled. The hearths in succession from top to bottom are alternately what is commonly termed "in" or "out" hearths, i.e., an "in" hearth is one on which the material is moved toward the center

and is so constructed that an opening is left around the shaft allowing the material to drop to the next hearth which is an "out" hearth upon which the material moves toward the periphery and passes through drop holes spaced around the periphery onto the next hearth, which is an "in" hearth, etc., until the material is discharged from the last hearth which is an "out" hearth.

From the vacuum filter, the filter cake drops directly onto the drying, or top, hearth of the furnace, which is supposed to be warm enough to partially dry the sludge before it enters the furnace to the No. 1, or uppermost, hearth within the furnace. The rabble arms and teeth on this drying hearth are supposed to scrape the sludge, of about 50 per cent moisture content, across the dry plate and through a 6 in. by 6 in. hole where it drops onto the No. 1 hearth. The effectiveness of this operation will be discussed later.

During these tests, the reburned lime discharging from the furnace was collected in buckets, weighed, allowed to cool, and either sacked and put into storage or fed directly back into the system by means of a dry chemical feeder.

Chemical Feeding and Slaking

During a re-use test the lime from the kiln was dumped into the bin of the dry chemical feeder as soon as it had cooled sufficiently, which generally took about four hours. The feeder discharged directly into an open 50-gallon drum equipped with a mechanical agitator, rotating at 36 r.p.m., which acted as a lime slaker. Because of the small quantity of chemicals handled, and because the lime was slaked with cold water, a 5-kilowatt immersion heater was installed in the slaker tank to assist in maintaining the correct slaking temperature within the tank. During most of the tests this temperature was kept between 170° and 200°F.

The slaker discharged from near the top of the tank into another barrel where make-up water was added before the lime slurry entered a piston pump which lifted it to the point of mixing with the raw water entering the reaction flocculator.

As mentioned in the general description of the Estabrook process, enough raw water is diverted to the reaction clarifier to dissolve the lime needed for the treatment of all the water. In the case of the Colorado River water, this amounts to from $12\frac{1}{2}$ to about $17\frac{1}{2}$ per cent of the total flow, depending upon the hardness characteristics

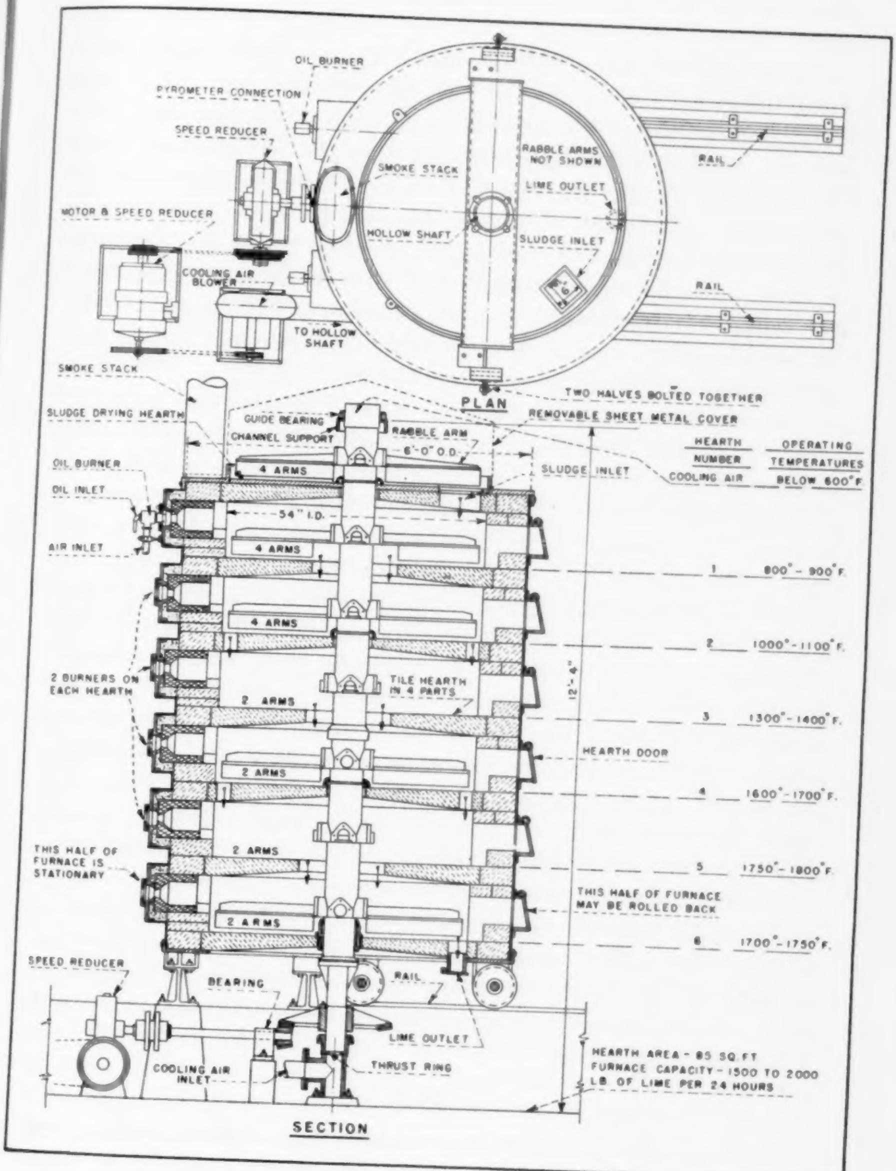


FIG. 3. Nichols Herreshoff Furnace.

of the raw water. To this water was mixed the lime slurry from the slaker.

The mixture of water and lime entered the top of a 50-gallon drum where turbulence accomplished the necessary mixing. From the bottom of the drum the dosed water flowed to the bottom of the reaction flocculator and then upward past the baffles while being stirred by the paddles rotating at 4 r.p.m. The reaction flocculator and clarifier which were used were designed for other purposes and consequently provided a much longer detention than might normally be used. The flocculator consisted of an 8 ft. diameter galvanized iron tank, 13 ft. 6 in. deep with active storage of 4,700 gallons. The tank was supplied with a specially designed baffle and paddle flocculator assembly made by the Dorr Company.

From the top of the flocculator the water flowed through a 10-inch pipe to the well of a standard center-feed Dorrco clarifier. The mechanism was in a 15-ft. 4 in. diameter bolted steel tank with an effective depth of 14 ft. 11 in. This provided a 20,700-gallon active storage. The insolubles and precipitates were settled out in this tank. The effluent from the clarifier was taken off by a peripheral overflow weir which discharged through a 6-inch and then through a 3-inch pipe to the point of chemical application in the main Boulder City plant. This effluent was a practically clear, caustic solution, containing the necessary calcium hydroxide to treat the remaining water with which it was mixed in the main plant. This caustic solution was mixed with the raw water at the same point as the soda ash and/or other chemicals were added to the water. From this point, the water treatment followed conventional practice. Excess lime was carried through the primary clarifier basin in order to remove from the water as much of the magnesium as possible.

The sludge from the primary and secondary clarifiers was pumped to the sludge storage tank feeding the vacuum filter, as previously mentioned. The sludge from the reaction clarifier was pumped to waste as it contained the magnesium and other constituents which it is desired to eliminate.

Test Procedure

After the erection and preliminary testing of the equipment, the period covered by these tests was from January 11 to April 29, 1938. From January 11 to January 21, reburned lime was produced as a reserve supply and in order to obtain additional information on the

operation of the vacuum filter and the calcining furnace before the main tests were started. On January 22, the main Boulder City plant started to operate using the reclaimed lime as supplied to it through the split treatment of the Estabrook process. This test of re-use was made continuously from that time until February 23, when it was terminated due to a shortage of reclaimed lime. During this test, as explained later, it was found that the sludge produced when the clear lime solution and soda ash were added to the raw water was so fine or colloidal that it was impossible to produce a satisfactory filter cake on the vacuum filter.

After some minor repairs, reclaimed lime was produced as a reserve supply from March 1 through March 8. Starting March 9, the Boulder City plant was again operated with the reclaimed lime. This test was identical with the first, except that during this test a coagulant, ferrous sulfate or copperas, was added at the same point as the clear lime solution and the soda ash in an endeavor to produce a sludge of larger particle size which could be handled on the vacuum filter. This test was concluded on March 31.

In order to obtain comparative data relative to the conclusion that magnesium and other undesirable constituents will build up in the reclaimed and re-used lime if some method is not used to eliminate them, a test was started on April 1 and run until April 9 in which the slaked, reclaimed lime was fed directly back to the mixing basin of the Boulder City plant without going through the split treatment of the Estabrook process.

Filter and Furnace Operated Continuously

During lime reburning tests, the filter and furnace were generally operated continuously, 24 hours per day. When lime was being reclaimed, sludge from the main clarifiers was pumped to the sludge storage tank which fed the vacuum filter. This sludge pumping was generally done at frequent intervals but for a short period of time, in order to obtain as thick a sludge as possible. The vacuum filter was operated continuously, being fed slightly more sludge than was required, so that the pick-up reservoir was always full to the overflow pipe. This maintained uniform operating conditions for the filter. The discharge chute from the filter led directly to the dry hearth of the furnace. At least twice a day, samples of the sludge going to the filter and of the filter cake leaving the filter, were taken for moisture determination. One of the dried sludge samples was

then used for a gravimetric analysis to determine the calcium, magnesium, and other constituents in the sludge.

On each of the inner six hearths of the Nichols Herreshoff furnace was placed a thermocouple which was connected to a selector switch located on the platform beside the filter. In addition there was a thermocouple placed in the hollow center shaft of the furnace about 15 in. below the top to measure the temperature of the discharged cooling air from the arms and shaft. The temperature at these 7 points was measured and recorded at least every half-hour with a Leeds and Northrup potentiometer pyrometer. In addition, the normal air temperature was recorded hourly from a sheltered mercurial thermometer. The general furnace operation will be discussed later.

The reclaimed lime discharging from the furnace was caught in a bucket and the contents weighed. A representative sample was taken from each bucket by means of a cylindrical sampling tube which was pushed to the bottom, thereby obtaining a sample for the entire depth of the bucket. These samples were then composited over a 24-hour period, the composite being thoroughly mixed and determinations made for "available lime," calcium, magnesium, silicates, R_2O_3 (Al_2O_3 and Fe_2O_3 reported together as R_2O_3), and other inerts.

The water to the reaction clarifier was metered and checks were periodically made to make sure that the amount of water going through was correct, and alkalinity and turbidity determinations were made of the caustic solution returning to the main plant from the reaction clarifier. Occasional analyses of the caustic solution also were made to determine the amount of magnesium returning to the main plant in this solution.

A record was kept of the amount of reclaimed lime which was fed during the re-use tests, as well as the temperature within the lime slaker. The data on the operation of the Boulder City plant were obtained from the regular reports made by the Bureau of Reclamation operators. As there were changes indicated in the quality of the raw water entering the main plant, gravimetric analyses were made of this water and of the softened water.

The operation of each major item of equipment will be taken up separately, for it is felt that the information and data gathered during these tests, which covered a period of six months, will be valuable to anyone interested in this problem of reclamation.

The 3 ft. by 1 ft. experimental Oliver vacuum filter was driven by

a variable-speed mechanism whereby the drum speed could be varied from one revolution in 1½ minutes to one revolution in 3½ minutes. After numerous tests within this speed range, the most satisfactory filtering results were obtained at one revolution in 2½ minutes. Three different cotton filter cloths were tried, an 074 drill, an 078 drill, and a 150 twill. The latter cloth gave a higher rate of filtration than either of the others and at the same time produced a relatively clear filtrate and had remarkable wearing qualities. One of these 150 twill cloths lasted for approximately six weeks of continuous operation without indications of excessive wear.

During the period when filter results were considered representative, the applied vacuum remained very constant at about 17 in. of mercury. The air pressure for blow-off was 4½ lb. per sq.in.

TABLE 1

Vacuum Filter Operation

DATES INCLUDING MARCH	MOISTURE CONTENT		FILTER CAPACITY; DRY WEIGHT OF SLUDGE	CHEMICAL COMPOSITION OF UNBURNED SLUDGE		
	Filter feed	Filter cake		$CaCO_3$	$Mg(OH)_2$	Inerts
	per cent	*per cent*	*lb. per hour*	*per cent*	*per cent*	*per cent*
7/12	75.6	49.6	80.7	87.2	10.2	2.6
14/19	78.0	49.6	75.9	88.0	8.8	3.2
21/26	76.8	49.6	75.9	86.4	9.1	4.5

The general results obtained may best be visualized by an inspection of table 1, which gives the average operating data for three consecutive weeks of operation during the re-use test, using ferrous sulfate as a coagulant. These data are representative of the results obtained during all of the second Estabrook test. The plant was not operated on Sundays during this period. A filter capacity of 75.9 lb. per hour on the experimental filter used, which has a filtering area of 9.4 sq.ft., is equivalent to 194 lb. per sq.ft. per 24 hours, dry weight.

Laboratory tests made with this same sludge by the Dorr Company at its Westport laboratory indicate that by heating it to a temperature of 60°C. the filter rate may be more than doubled. With the experimental plant arrangement, it was impossible to heat satisfactorily the sludge going to the filter. However, in a plant properly designed for it, the exhaust gases from the calcining furnace could readily be used for this purpose.

Under "Test Procedure" above, it was mentioned that trouble

was encountered in trying to filter the sludge produced during operation when the clear lime solution from the Estabrook process was added with the soda ash to the raw water, without the use of a coagulant. This procedure of adding the lime and soda ash direct to the raw water without a coagulant is the usual procedure at the Boulder City plant. The preliminary reburning tests, made when the main plant was operating with commercial hydrated lime (before the re-use tests were started) indicated that the sludge produced would filter excellently on a vacuum filter. A filter capacity of about 400 lb. per sq.ft. per 24 hours was obtained during this period. As soon as the re-use tests using the Estabrook process were started, the filter capacity began to decrease, falling as low as 68 lb. per sq.ft. per 24 hours. At this low capacity, it was impossible to make sufficient reburned lime to operate the Boulder City plant. Different mixing and flocculation tests were made to try to improve the condition of the sludge produced, but to no avail. A microscopic examination of the sludge showed it to consist of smaller crystals than the original sludge, some of the material being practically colloidal. Consequently, the re-use tests were stopped until equipment was obtained to feed a coagulant with the lime and soda ash.

The coagulant used was ferrous sulfate, or copperas. This coagulant was selected not as a result of any tests indicating its superiority for this purpose, but because it was easier to handle than ferric chloride and because it was thought that better results would be obtained with it than with alum in the pH range prevailing. Should the Estabrook process be adopted, a separate study should be made to ascertain the best coagulant to use with the water and under the conditions existing.

The addition of the coagulant with the clear lime solution from the reaction clarifier of the Estabrook process and the soda ash, mixed with the raw water, materially increased the thickness of the filter cake on the vacuum filter. While the sludge did not handle so well as that produced during normal treatment, it did filter sufficiently well to show that partial unwatering of the sludge on a vacuum filter was feasible, which was not the case with the Estabrook process before the coagulant was used. This is a phase of the work which needs more investigation.

No attempt was made to obtain power consumption figures on the experimental filter, for the compressors and pumps used were considerably over-capacity. The test work indicates that necessary supervision would be minor for a commercial filter installation.

Furnace Operation Analysed

When analyzing and interpreting the data collected on the operation of the Nichols Herreshoff lime calcining furnace, it should be noted that this furnace is a so-called laboratory model which does not include the insulation or mechanical design found in a commercial unit. The furnace is large enough, however, to give a very good idea of what may be expected in the operation of a large unit.

As shown in fig. 3, the furnace contains six burning hearths and one drying hearth—the top. It was recommended by the manufacturers that the temperatures be maintained in the furnace as follows:

Hearth #1— 800–900°F.
Hearth #2— 900–1000°F.
Hearth #3—1300°F.
Hearth #4—1600°F.
Hearth #5—1700°F.
Hearth #6—1750°F.

Hearth #1 is the uppermost hearth within the furnace and hearth #6 is the bottom one. Cooling air discharged from the center shaft is allowed to reach 600°F., due to the fact that Pyrocast rabble arms and teeth were used in the furnace construction. It was found in operation, however, that better results were obtained if the temperature on the #5 hearth was kept between 1,750 and 1,800°F. and on #4 up to about 1,700°F. It was also found that when operating the furnace near its rated capacity, it was necessary to keep the temperatures on the top hearths higher in order that the drying hearth would be sufficiently warm to dry the filter cake dropping onto it so that it would rabble and drop through the port leading to the #1 hearth. After the furnace had been used long enough for a protective coating of lime dust to collect on the rabble arms, rabble teeth, and center shaft, the discharged cooling air remained quite uniformly between 450° and 500°F. There was, of course, some variation in this temperature due to changes in the outside air temperature.

It is apparently necessary to keep the temperature of the lower hearths up to the calcining temperature in order not to reverse the reaction $CaCO_3$ + heat = $CaO + CO_2$. There is, however, considerable heat given off with the burned lime as it drops out of the furnace. Means could be employed to recover some of this heat if it were desired.

One test of the operation of such a furnace is the quality of the

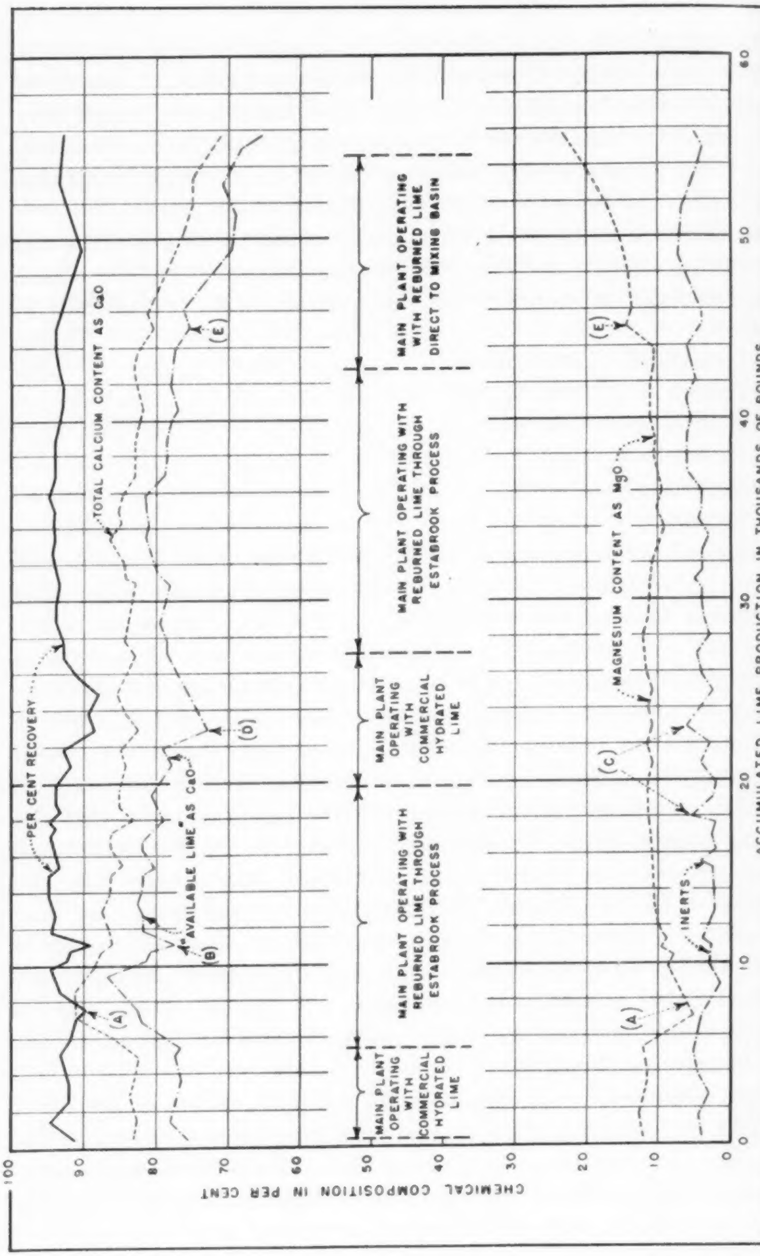


FIG. 4. Quality of Lime Produced. See text for further explanation.

product produced. Table 2 covers the same period as the data given for the vacuum filter operation, table 1. The "available lime" is the calcium oxide content which will enter into the water softening reaction as determined by the U. S. Bureau of Standards method of analysis. The "per cent recovery" is the ratio of "available lime" to total calcium expressed as CaO. The "per cent recovery" is one of the best indices of the efficiency of the furnace operation, for it shows whether the material is being properly burned within the furnace. A recovery of over 90 per cent is considered very good. The furnace capacity or production as given in table 2 is not what the furnace was capable of turning out, but is simply the rate at which the vacuum filter was able to deliver filter cake to the furnace. This will be discussed later in greater detail.

TABLE 2

Lime Calcining Furnace Operation

DATES INCLUDING MARCH	OPERATION	PRODUCTION		COMPOSITION OF FURNACE PRODUCT				
		Total	Unit	Available CaO	Total CaO	MgO	Inerts	Recovery
	hours	*lb.*	*lb./hr.*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
7/12	126.5	5717.5	45.2	78.5	84.0	11.8	4.2	93.5
14/19	100.2	4261.5	42.5	80.4	85.1	10.2	4.7	94.5
21/26	129.7	5512.5	42.5	78.9	83.4	10.5	6.1	94.6

The results obtained during this period were by no means exceptional for the quality of the lime produced during the entire lime reburning program was consistently good. During the period a total of 56,074 lb. of lime was produced. It was found during the tests that whenever there was a variation in the results obtained from the furnace, a reason for this variation could usually be found. It was soon evident that the method used for collecting the lime as it discharged from the furnace allowed considerable air slaking to occur. This was quite marked during rains or high humidity, as fig. 4 shows.

In fig. 4, per cent of recovery is the ratio of "available lime" to total calcium as CaO, "available lime" being the calcium oxide content which enters into the water softening reaction as determined by the U. S. Bureau of Standards method of analysis. Inerts include constituents other than calcium and magnesium such as silica, iron, alumina, sulfates, etc. Points of special interest are noted in fig. 4 as follows: (A) high calcium and low magnesium content of lime caused by dumping the calcium carbonate secondary

clarifier sludge into the primary clarifier basin; (B) low "available lime" due to an attempt to feed sludge direct to furnace without use of vacuum filter, loading furnace beyond its capacity; (C) the periodic peaks in quantity of inerts attributable to high winds blowing sand into clarifier basins—the gradual increase in inerts, after producing 28,000 lb., due to increase in iron content from addition of ferrous sulfate as a coagulant; (D) low "available lime" caused by rains air-slaking the lime between the furnace discharge and the point of sampling; (E) decrease in calcium content and increase in magnesium due to direct re-use of reburned lime in Boulder City treatment plant chemical mixing basin.

It will be particularly noted that the "per cent recovery" generally is above 90 per cent. For over a month, this averaged from 93.5 to 94.6 per cent and at one time reached 95.2 per cent. The significance of the chemical composition of the lime will be discussed below.

The general physical quality of the lime appeared very good. When not using ferrous sulfate as a coagulant, it was a very fine, white powder with occasional small soft lumps very little larger than a pea. When using ferrous sulfate as a coagulant, the lime was not quite so fine and was tan or light brown in color. Otherwise it was little different from that produced without the use of a coagulant. It appeared to handle very well in the slaker. However, comparative tests made at the Westport Laboratory of the Dorr Company led their chemist to conclude that "slaking tests indicated that the reburned lime does not slake quite as readily nor as thoroughly as the usual good grade dry lime." Whether this is due to the difference in particle size, to the lower "available CaO" content and the correspondingly higher amount of magnesium, or to the burning of the lime itself, is not known. It is likely that it is primarily the first factor although the others undoubtedly influence the results also. In general, the physical characteristics of the reburned lime are excellent for use in the water treatment processes.

The correlation of the results obtained with the Laboratory Type furnace which was used, and a commercial sized unit, is somewhat difficult. Particularly is this true in the study of the fuel consumption. The oil which was used during the entire test program was Standard Stove Oil which has a relatively low B.t.u. content of 136,500 to 137,000 B.t.u. per gallon. This will have to be compared with commercial grades of fuel oil which would be used for large units which will have a rating of 150,000 to 151,000 B.t.u. per gallon. As the insulation of the experimental furnace was ma-

terially less than would be on a commercial unit, the fuel necessary to make up for heat losses amounted to a considerable part of the total fuel required. Two separate tests were made to try to determine the fuel requirement for heat losses, one for 31.5 hours and the other for 40 hours. During these tests the furnace temperatures were maintained as closely as possible to the average temperatures which were used during the lime reburning process, but no sludge was put through the furnace to be calcined. Therefore, the only fuel use was to make up for the heat losses. In the first test, the temperatures on the lower hearths were allowed to go down to 1630°F. and the fuel consumption averaged during the entire period 2.80 gallons per hour. In the second test, the temperatures were maintained between 1750 and 1800°F. on the lower hearths and the average fuel consumption during the period was 3.52 gallons per hour. For a 24-hour period, this amounts to 84.5 gallons. Even on a commercial sized unit, there will be some fuel required to make up for the heat losses, but it is probable that requirement would be very little more, or possibly even less, than on this small unit.

Fuel Consumption Varied in Test

The actual fuel consumption per ton of CaO produced varied greatly with the amount of sludge which was being fed through the furnace. For only a short period did the furnace operate at near capacity (82.5 to 97.2 lb. per hour) at which time the fuel consumption varied from 107 to 117 gallons per ton of burned lime produced. The actual hourly oil consumption did not vary greatly with the amount of sludge which was being fed through the furnace, a 100 per cent increase in rate of feed increasing the oil consumption only 50 per cent. This again indicates that the major portion of the fuel was required to compensate for radiation and other heat losses. Recent communication with the manufacturer indicates that they are willing to guarantee a fuel consumption on commercial installations of 65 to 70 gallons per ton of CaO produced. This appears to be somewhat less than the amount of fuel required by modern rotary kilns.

The "per cent recovery" in the lime produced from the furnace was directly correlated to the hearth temperatures maintained within the furnace. It would therefore appear desirable in a commercial unit to install thermostatic control on the hearth burners.

Upon the completion of the tests, the furnace was opened for inspection. Several of the hearth tiles were found to be cracked but

were not damaged sufficiently to interfere with the furnace operation. It is reported by the manufacturer that these cracks can be satisfactorily repaired with refractory cement.

The major difficulty encountered was in the rabbling of the filter cake on the top, or drying, hearth. The filter cake, as it discharged from the vacuum filter, contained about 50 per cent moisture and was about the consistency of moist clay. If the iron top hearth and rabble teeth were sufficiently hot, the filter cake, as it dropped onto the hearth, formed small lumps about the size of a hickory nut which rabbled very well, being gradually scraped across the hot plate until they fell through the port onto the No. 1 hearth within the furnace. When the top hearth and rabble teeth were not sufficiently warm, the filter cake stuck to both the hearth and the teeth, adhering tenaciously, and finally formed a solid cake of sludge on the entire hearth, bridging the port to the No. 1 hearth but not dropping into it. In the larger commercial units, the spacing and the length of the rabble teeth are much greater, which should eliminate to a considerable extent the bridging of the sludge between the teeth.

The power consumption for the experimental furnace was between 40 and 50 kw. hr. per ton of lime produced, when operating near capacity.

For permanent lime calcining plants, where proper conveyors are provided from the furnace discharge, the operation can be handled by one man to look after the filters and another man to operate the furnace.

Miscellaneous Operations Described

The feeding and slaking of the lime for these tests is identical with normal procedure in present water treatment plants. The reburned lime appeared to slake just as satisfactorily as commercial lime when the temperatures within the slaker were maintained at the usual 170 to 200°F. The detention within the slaker was approximately 20 minutes.

Because of the layout of the Boulder City plant and the experimental equipment, it was necessary to pump the diluted milk of lime from the slaker receiving tank to the small mixing tank on the top of the flocculator. A duplex piston pump was used for this purpose which, while satisfactory for these tests, would not be at all suitable for permanent installations. It was necessary to replace the piston cup leathers and to repack the pump at least once a week, at which

time the pump valves and the discharge hose were thoroughly cleaned. The lime slurry was quite abrasive and in addition rapidly clogged the valves and the discharge lines.

The turbulence produced from the discharge of the raw water into the small mixing drum was sufficient to mix the water thoroughly with the lime slurry which also entered the drum. Numerous tests indicated that adequate mixing was always being procured.

The water from the mixing drum entered the flocculator tank tangentially at the bottom of the tank and discharged through a side outlet at the top. The mechanism in this tank was referred to in the general description of the plant. During the two separate tests of the Estabrook process, the average rate of flow through the reaction flocculator and clarifier was 76 g.p.m. In the first test, this amounts to 16.5 per cent of the total flow, and in the second test, it is 14.4 per cent of the total flow. In each case, therefore, the detention within the flocculator tank was approximately 1 hour. The results obtained in the flocculator did not always appear to be as good as could be desired. Various speeds of rotation of the flocculator paddles were tried, within the range of the equipment, with no appreciable change in the results from those obtained at 4 r.p.m. or 1.5 ft. per second tip speed. The results indicate that further investigations should be made of this phase of the process in order to obtain optimum results. Possibly this highly concentrated lime mixture, nearing saturation, may require considerably more agitation to produce a satisfactory floc.

The clarifier used for this purpose was particularly designed for other tests and, as a consequence, provided a longer detention period than might normally be used. At the average rate of flow during these tests, the detention was 4 hours and 34 minutes. It was believed that with this detention a very clear caustic effluent would be obtained. However, turbidities ranging from 3 to over 100 p.p.m. occurred, the average during normal operation being generally less than 15 p.p.m. As would be expected, the turbidity carried over consisted primarily of magnesium hydroxide floc which, of course, was not desirable. The amount carried over was not sufficient to affect materially the quality of the sludge produced in the primary clarifier of the main plant, as is shown by the analyses of the lime produced. It is probable that if a better floc were formed in the flocculator a more satisfactory effluent would be obtained from the clarifier. This phase of the process also needs further investigation.

Process Considered Efficient

It was explained in the early part of this report that the purpose of the Estabrook process is to eliminate the build-up of the undesirable magnesium in the reclaimed lime so that it can be continually re-used as a softening agent. The tests show conclusively that the method does accomplish this purpose.

At the start of this test, before using any reclaimed lime in the main plant operation, the sludge from the primary clarifier was entirely pumped out to eliminate any effect of the sludge produced from the regular treatment with commercial lime. As a result, several days elapsed before any primary sludge was available for reburning. An endeavor was made to use the secondary sludge, which consisted of calcium carbonate with a small amount of activated carbon, but difficulties were encountered in the vacuum filter operation. These difficulties were due to the filter working too well and the furnace not being able to handle the quantity of sludge produced by the filter. In filtering this calcium carbonate sludge, a cake of over 1 in. thickness was produced, while in the filtering of the regular sludge containing some magnesium hydroxide, the cake thickness averaged only 3/16 inch. Due to the plant arrangement, it was necessary to dump this secondary sludge into the primary clarifier. Therefore, in this primary basin, which contained very little primary sludge, there was mixed a large quantity of pure calcium carbonate sludge. The effect of this upon the quality of the lime produced was very marked and was evident throughout about half of this first test. It should be noted, however, that this secondary sludge can be and would be used in regular operation but it should probably be mixed with the primary sludge and would merely "sweeten it up."

In the first test, 8,617,000 gallons of water were softened using 18,476 lb. of reclaimed lime as one of the softening agents. It is computed that in treating this quantity of water, the lime went through an average of at least 8 complete cycles of reburning and re-use. During these 8 cycles, the magnesium content in the reburned lime, expressed as MgO, varied from a minimum of 5.6 per cent to a maximum of 11.7 per cent. As stated, the effect of the secondary sludge was appreciable during the first half of this test, as shown by a relatively high calcium content and correspondingly low magnesium content of the reburned lime. The concentration of magnesium should be compared to that existing before the lime was re-used which averaged 12.15 per cent.

In the second test, during which ferrous sulfate was used as a coagulant, 7,631,000 gallons of water were softened with 16,378 lb. of reclaimed lime. In this test, it is computed that an average of at least 7 complete cycles of reburning and re-use were accomplished. During this test, the magnesium content of the reburned lime, expressed as MgO, was much more uniform, ranging from a minimum of 8.0 to a maximum of 10.7 per cent. There was no indication during the test of a build-up of the magnesium in the lime, but merely fluctuations as a result of other tests which were being carried on at the same time.

Direct Re-use Causes Build-up of Magnesium

In order to prove conclusively whether the magnesium would build up in the lime, unless some method were used to eliminate it, a short test was made wherein the reburned lime was fed directly back to the mixing basin of the main plant. In this test, 4,269,000 gallons of water were softened with 8,196 lb. of reburned lime, which provides an estimated average of from 3 to 4 cycles of re-use. The build-up of the magnesium was very rapid, as indicated by figure 4, increasing from 11.0 per cent at the start to 24.2 per cent when the test was concluded. It is therefore very evident that direct re-use would not be satisfactory with a water of this type.

Mention has already been made of the difficulty encountered by adding the clear lime solution from the reaction clarifier with the soda ash in the mixing basin of the main plant. This appears to be one of the major problems to be worked out in the Estabrook process. While fairly satisfactory results were obtained after adding the coagulant at this point, it is felt that the results could be materially improved. It is probable that by experimentation with different coagulants and with different mixing, flocculation time, and velocities, better floc and sludge conditions might be procured.

The basis of the Estabrook process is that just enough water be used in the "reaction" phase to dissolve the lime for the entire quantity of water to be treated. So many factors influence the solubility of lime that it is practically impossible to determine the minimum amount of water which is necessary to take this lime into solution. For the purpose of these tests, it was assumed that the solubility of calcium oxide was 1.31 grams per liter of water. The theoretical amount of water required for the "reaction" phase was determined to be 12.4 per cent for the first test and 12.3 per cent for the second

test. In order to be sure sufficient water was used to allow all the lime to be taken into solution, it was decided to use a 15 per cent split for both tests. The average for the entire test actually worked out to be 16.5 per cent for the first test and 14.4 per cent for the second test. Even with this apparent excess amount of water, an analysis of the results obtained during the tests indicates that there was 21.4 per cent of the lime in the first test and 20.8 per cent of the lime in the second test which was unaccounted for or which did not go into solution and which was lost. It therefore appears that it is necessary to use considerably more than the theoretical amount of water in the small split or "reaction" phase of the Estabrook process.

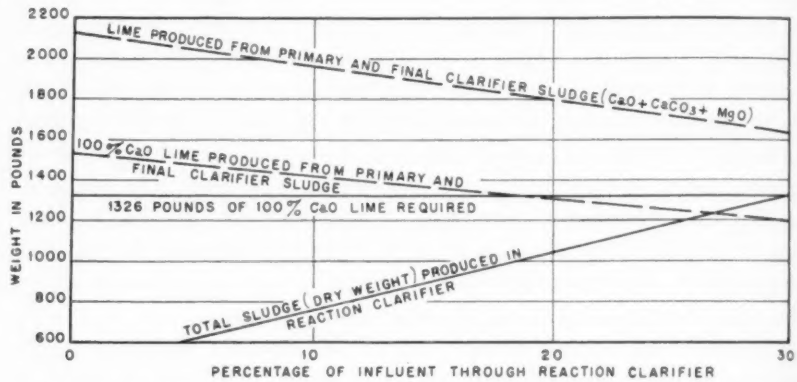


FIG. 5. Relation between Per Cent of Split and Lime Produced. This graph is based on the long time average analysis of Colorado River water of 300 p.p.m. total harness and 145 p.p.m. carbonate harness, softened to a total hardness of 125 p.p.m. All quantities are based on a flow rate of one million gallons per day.

This may become a decided disadvantage, for the greater the split the smaller the quantity of lime which will be available to be reclaimed. In the case of average Colorado River water, it is necessary that the split shall be not greater than 18.5 per cent, or there will be insufficient lime recovered from the sludge to satisfy the requirements for softening, as indicated in fig. 5. Of course, make-up lime can always be introduced, but it is preferable to be able to reclaim the entire amount required.

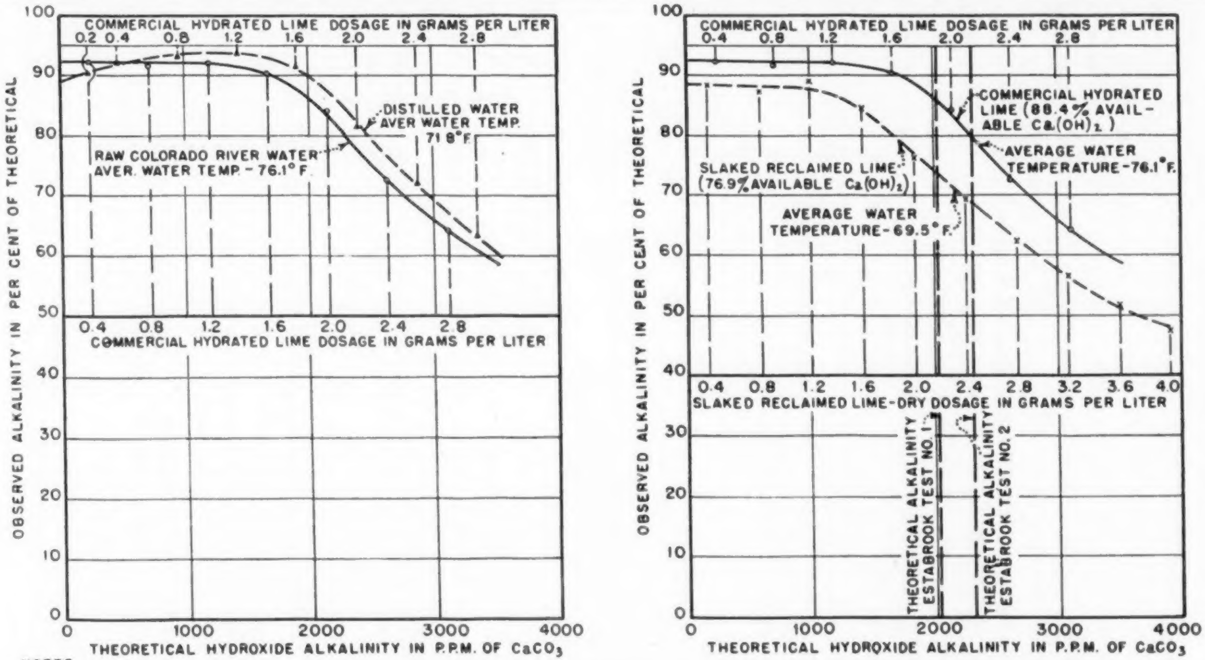
A general summary of the results obtained during the Estabrook tests and during the corresponding direct re-use test, is given in table 3. The data in this table are the weighted averages of the results

TABLE 3

Summary of Lime Reclamation and Reuse Tests

(Averages for the entire test period)

	Estabrook Process		Direct Reuse
	Test #1	Test #2	
Water Analysis			
Raw:			
Total hardness as $CaCO_3$ .... p.p.m.	329	348	350
Carbonate hardness as $CaCO_3$ ...... p.p.m.	122	126	127
Magnesium as Mg .... p.p.m.	25	25	25
Treated:			
Total hardness as $CaCO_3$ .... p.p.m.	104	100	98
Carbonate hardness as $CaCO_3$ ...... p.p.m.	34	33	29
Magnesium as Mg .... p.p.m.	4	4	4
Main Plant			
Total water treated—1,000 gal.	8,617	7,631	4,269
Average rate of flow .... g.p.m.	460	528	566
Hours of plant operation	312.2	241.1	125.7
Caustic alkalinity of effluent from primary clarifier .... p.p.m. $CaCO_3$	82	75	84
Reaction Plant			
Average rate of flow .... g.p.m.	76	76	0
Percentage of total flow	16.5	14.4	—
Caustic alk. of reac. clarifier eff. p.p.m. $CaCO_3$	1,580	1,730	—
Total alk. of reac. clarifier eff	1,620	1,765	—
Theoretical caustic alk. from lime added....	2,030	2,306	—
Actual caustic alk. as % of theor. .. per cent	77.8	75.0	—
Chemicals Added			
Lime—total .... lb.	18,476	16,378	8,196
Lime—per million gal. .... lb.	2,144	2,146	1,920
Available CaO—per million gal. .... lb.	1,726	1,695	1,369
Soda ash—per million gal. .... lb.	1,320	1,500	1,476
Ferrous sulphate—per million gal. .... lb.	—	10	—
Composition of Reclaimed Lime			
Available CaO at start of run .... per cent	76.5	78.7	78.0
Available CaO at end of run .... per cent	80.5	78.0	66.6
Available CaO—weighted average .. per cent	80.5	79.0	71.3
Magnesium as MgO—at start of run per cent	12.1	12.6	11.0
Magnesium as MgO—at end of run .. per cent	11.4	11.0	24.2
Magnesium as MgO—weighted average per cent	11.3	10.9	17.0
Theoretical Chemical Requirements			
CaO to treat all water—per m.g. .... lb.	1,357	1,342	1,388
Unaccounted for CaO which was added per cent	21.4	20.8	—
Na_2CO_3 to treat all water—per m.g. ..... lb.	1,212	1,371	1,362
Unaccounted for Na_2CO_3 which was added per cent	8.2	8.6	7.7
Reaction Clarifier "Split" Requirements			
From theoretical lime dosage—at solubility of 1.31 gr./liter .... per cent	12.4	12.3	—
From actual lime dosage—at solubility of 1.31 gr./liter .... per cent	15.7	15.5	—



NOTES

BASED ON 60 MINUTES MIXING IN STOPPERED BOTTLE. THEORETICAL ALKALINITY CALCULATED FROM AVAILABLE $Ca(OH)_2$ IN LIME USED AND THAT REQUIRED TO SOFTEN THE RAW WATER USED. COMMERCIAL HYDRATED LIME USED, CONTAINING 88.4% AVAILABLE $Ca(OH)_2$ LIME DOSAGE IS TOTAL WEIGHT OF LIME ADDED TO WATER. RAW COLORADO RIVER WATER USED CONTAINED 128 P.P.M. CARBONATE HARDNESS AND 25 P.P.M. Mg.

FIG. 6. Left: Lime Solubility in Raw and Distilled Water. Right: Relation of Lime Solubility to Concentration

during the entire test period in each case. From an inspection of these data, it is readily apparent that a considerable portion of the lime added in the reaction phase of the treatment did not go into solution. The problem of the efficiency of the chemical utilization, which is very evident from these tests, is one which undoubtedly needs investigating in every softening plant. A comparison of the efficiency obtained in the feeding of the soda ash in this case with that obtained at other plants using this chemical, would be of interest.

Lime Solubility Tested

A series of laboratory tests was conducted to ascertain the actual lime solubility which might be expected when using Colorado River water as the solvent. For comparative purposes, both distilled water and raw Colorado River water were used, and parallel tests run on commercial hydrated lime and on slaked and dried reclaimed lime produced during the main tests. These tests were run using stoppered $2\frac{1}{2}$-liter reagent bottles. In each case, 2 liters of water were used and the proper quantity of lime added to the water, the bottle stoppered, and then shaken intermittently by hand to keep the lime in suspension. At intervals of 5, 15, 30, 60 minutes, and in some cases longer, portions were removed from the bottle, while vigorously shaking to keep the lime in uniform suspension, filtered, and titrated for alkalinity.

When referred to a comparable basis, the solubility of the lime in distilled water was practically identical to that in raw Colorado River water, as is shown by fig. 6. The comparison of the solubility of the Metropolitan Water District slaked lime with that of commercial hydrated lime is shown by fig. 6. It is evident from these charts that the slaked reburned lime is not so soluble as the commercial lime. This is possibly due to the difference in particle size, the commercial lime having been ground to pass a #200 sieve and the reburned lime having been only superficially ground in a laboratory mortar and pestle. On the same figure is indicated the average dosage which was actually used in the reaction phase of the treatment during the reclamation tests. It is shown by these data that if a small split is used in this Estabrook process, a considerable amount of the lime entering the reaction clarifier does not dissolve and is settled out with the magnesium sludge and is discharged to waste.

An estimate has been made of the cost of operation of a lime reclamation plant capable of handling the sludge from a treatment

plant of 100 m.g.d. capacity, in order to determine the economic feasibility of reclaiming lime for re-use.

The size of vacuum filters and lime calcining furnaces will, of course, depend upon the amount of hardness being removed from the water and the method of lime reclamation adopted. For this estimate it has been assumed that the Estabrook method of reclamation will be used and that a kiln capacity of about 100 tons per 24 hours will be installed.

As previously discussed, one of the purposes of lime reclamation is to reduce the amount of sludge which must be disposed of. Any material reduction in the quantity of sludge handled would, under conditions prevailing on the Pacific Coast, effect a saving in the cost of this sludge handling. Such a saving is impossible to evaluate hypothetically for it is primarily dependent upon the value of the

TABLE 4

Cost per Ton of Lime Produced, Operation at 100 per cent Load Factor

Fuel at 90 gal. per ton and oil at $1.10 per bbl.	$2.35
Power for filter, kiln, and Estabrook flocculator and clarifier at 55 kw. hr. at 1¢ per kw. hr.	.55
Operation—2 men per shift at $6.00 per day	.36
Maintenance	.15
Supervision, chemical control, etc.	.05
Interest and amortization—4 per cent interest and 40-year amortization	.83
Total operating cost per ton of lime	$4.29

land which must be acquired upon which to lagoon the sludge. Consequently, for this study no credit is allowed for this possible saving.

The total cost chargeable to the lime reclamation phase of a 100 m.g.d. plant embodying the Estabrook process, which would include the extra mixers, flocculators, clarifiers, basins, sludge thickening and heating, vacuum filters, lime calcining furnaces, and necessary structures, is estimated to be about $600,000.

Using the above figure for the plant cost which is chargeable to lime reclamation, operating data obtained from the Boulder City and subsequent investigations, and assuming fuel and power costs at prices which prevail on the Pacific Coast, the unit costs of operation may be derived as shown in table 4. It should be particularly noted that the above costs assume a fuel consumption of 90 gallons per ton, which is probably slightly above average for rotary kilns in this service.

It is therefore apparent that lime can be reclaimed from the treat-

ment plant sludge at a cost materially less than it can be purchased commercially. In softening plants using recarbonation, an additional saving would accrue by utilizing the stack gases as the source of carbon dioxide for this purpose.

Summary of Test Program

The entire lime reclamation test program covered the period from about November 1, 1937 to May 1, 1938. During this six-month period, the calcining furnace was fired 93 days and burned lime was produced 67 days of the time. The days on which the furnace was fired and no lime produced include those required for the preliminary testing, for slowly bringing up to temperature and cooling down, and week-ends when the furnace was kept hot so lime could be produced early on Monday morning. Generally, when lime was being produced, the filter and furnace were operated continuously 24 hours per day.

A total of 56,074 lb. of quick lime were produced during the lime-burning program and 20,516,000 gallons of water were softened with 43,050 lb. of reclaimed lime during the re-use tests. The excess lime which was produced and not used for the re-use tests was later fed to the Boulder City plant in its regular treatment procedure.

In order to maintain a close control on the operation of the lime calcining equipment, 1,893 separate samples of lime were taken and composited into 76 samples, which in turn were analyzed for "available CaO," R_2O_3, SiO_2, total calcium, and magnesium. There were, in addition to these 76 samples, 39 determinations made for "available CaO." There were 249 samples of sludge and filter cake taken for moisture determinations and on 83 of these dried samples, a complete gravimetric analysis was made for R_2O_3, SiO_2, calcium, and magnesium.

Table 5 gives a complete gravimetric analysis of representative composite samples of the reclaimed lime for each of the separate steps in the test program, and for the commercial hydrated lime used regularly at the Boulder City plant.

For the operation of the lime calcining furnace, there was used a total of 7,756 gallons of fuel oil. To maintain close temperature control of the furnace, pyrometer readings were taken every half-hour of operation on each of the 6 hearths and of the discharged cooling air from the center shaft. During these tests, a total of 3,424 sets of these 7 temperature readings was made.

Conclusions Drawn

The tests which were made by the District at Boulder City show conclusively that it is feasible, both from a chemical and an economic basis, to reclaim lime from the sludge produced during the water-softening process and to re-use this lime continuously as the softening agent. This not only makes available a low-cost lime, but accomplishes the other necessary purpose of materially reducing the amount of sludge which must be disposed of.

Two methods of eliminating the undesirable magnesium are described, the Estabrook process and the Hoover process. Only the Estabrook method was tried on full plant scale operation. A comparison of the laboratory results of the two processes indicates that the Hoover process should be just as satisfactory on full plant scale as the Estabrook process.

The Estabrook method of eliminating the build-up of the undesirable magnesium in the reclaimed lime definitely accomplishes that purpose. There were two problems encountered in this process which may retard the adaptation of it in the water softening field until they are satisfactorily solved. One is the difficulty in filtering the sludge produced when the clear caustic solution from the reaction clarifier is added to the other softening chemicals in the mixing basin of the main plant. This problem is alleviated by the addition of a coagulant in the main mixing basin which somewhat improves the filterability of the sludge, but the filter rate is still only half that existing when the lime is added as a slurry. The other difficulty is the loss in lime which occurs in the reaction clarifier because it does not go into solution. The laboratory tests on the solubility of lime indicate that this problem cannot be solved by an increase of mixing and reacting time, but apparently requires the addition of a greater quantity of water. Even with these difficulties, however, it appears that a considerable saving can be shown in the total treatment cost by the adaptation of the Estabrook or a similar process of lime reclamation.

In the Hoover process, these two particular difficulties are not present, for the lime is added as a slurry or milk of lime to the entire quantity of water to be treated. However, this method may require the addition of a coagulant in the secondary stage, along with the excess lime added to remove the magnesium, in order to precipitate the light magnesium hydroxide within a reasonable period of time. Close control of chemicals will also be required in the primary stage to avoid the precipitation of the magnesium in the primary clarifier.

The Estabrook process may have an advantage over the Hoover process in the elimination of possible build-up of the undesirable inerts or insolubles in the reburned lime. This is accomplished by adding the entire lime dosage ahead of the reaction clarifier in which these insolubles drop out with the sludge and are discharged to waste. There is some indication, however, as evidenced by the results at the Southend Waterworks Company in England and by the tests at Boulder City, that even with direct re-use these constituents, for some inexplicable reason, do not rapidly build up.

In initial cost, the Estabrook method will be somewhat less than the other method in that the extra flocculator and clarifier capacity required is only 15 to 25 per cent of the total, while in the Hoover

TABLE 5

Representative Lime Analyses

TEST DESCRIPTION	CHEMICAL COMPOSITION					
	SiO_2	R_2O_3	CaO	MgO	SO_3	Total
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Reburning during regular B.C. plant operation	1.2	0.5	84.3	12.3	1.7	100.0
Estabrook Test No. 1	1.2	0.3	86.5	10.2	1.8	100.0
Estabrook Test No. 2	1.1	1.4	86.1	9.5	1.9	100.0
End of reburning and direct reuse test	1.6	1.4	70.9	24.2	1.9	100.0
			$Ca(OH)_2$			
Commercial hydrated lime used in B.C. plant	1.4	0.6	85.3	10.7	2.0	100.0

method, they must be capable of handling the total flow. It is probable that the Estabrook process would be much more readily adapted to plants already constructed.

Should it be found desirable to increase the percentage split of the Estabrook process to 20 or 30 per cent, in order to obtain a greater solubility and utilization of the lime added, there will not be sufficient lime reclaimed when treating Colorado River water to satisfy the chemical requirements for softening. This is a disadvantage of the Estabrook process which is not the case with the Hoover process.

The Oliver continuous vacuum filter will satisfactorily dewater treatment plant sludge of the general quality of that encountered during these tests from an average moisture content of 80 per cent to an average of 50 per cent. The rate of filtration when used in

conjunction with the Estabrook process, without heating of the sludge, should be assumed not to exceed 200 lb., dry weight, per sq. ft. of filter area per 24 hours. With sludge heating, a capacity of 50 to 100 per cent greater than this might be possible. When used in conjunction with the Hoover process, where the sludge will consist almost entirely of calcium carbonate, the rate of filtration without sludge heating may be at least doubled, or 400 lb. per sq. ft. per 24 hours.

The results of these investigations show that a small lime calcining furnace of the multiple hearth type produces an excellent reburned lime when operating with the partially dewatered sludge. A recovery of over 90 per cent is readily obtained. Because the furnace was a small, so-called Laboratory Type, the fuel, power consumption and maintenance data are not believed to be representative of permanent large-scale installations.

Economic studies indicate that a definite saving can be obtained in the cost of the lime produced from the reclamation of the sludge from relatively large lime or lime-soda ash water treatment plants in addition to the saving which will accrue from the materially smaller amount of sludge which must be disposed of and in the production of the by-product carbon dioxide gas, which may be used for carbonation in the plant. For small plants, a separate study should be made wherein the effect of local conditions such as lime costs, difficulty of sludge disposal, etc., may easily influence the results in either direction.

The Colorado River Aqueduct construction is under the direction of F. E. Weymouth, General Manager and Chief Engineer, and Julian Hinds, Assistant Chief Engineer. The water treatment investigations were under the supervision of C. C. Elder, Hydrographic Engineer; and the writer was in direct charge of the experimental work at Boulder City, Nevada.

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Discussion by *Earl M. Kelly*.* The Metropolitan Water District and Mr. Aultman should be highly commended for their extensive and successful research program on the reclamation of water softening sludges. Heretofore, as mentioned in Mr. Aultman's paper, the final disposal of the voluminous precipitates from lime-soda ash softening plants has been a serious problem. Some work had been done on reducing the quantity of sludge through thickening or vacuum filtration, but even with such concentration methods, there still existed the troublesome handling of the remaining material.

Although new to the municipal water softening field, lime recovery through the sedimentation, filtration and calcination of calcium carbonate sludges has been practiced successfully for many years in chemical plants which manufacture caustic soda by the lime-soda ash process.

The caustic soda plant of the Stauffer Chemical Company at Dominguez, California, is an excellent installation where lime recovery is being carried out with ease on plant scale. This installation, which employs clarifiers, vacuum filter, kiln, classifier and slaker, is producing approximately 20 tons of CaO per day at present. The plant is exceedingly compact, and its simplicity of operation is attested by the fact that only one man per shift is required for normal operation.

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* Engineer, The Dorr Company, Inc., Los Angeles, California.

However, until the successful lime recovery work done by the Metropolitan Water District at Boulder City, no plant scale work had been done in this country on the reburning for re-use of sludges from municipal water softening plants, notwithstanding the successful chemical plant experiences.

Sludge Contents Restrict Re-use

The reasons are obvious from a study of the character of the sludges handled. The precipitate from the average caustic soda plant is almost entirely calcium carbonate. If high purity chemicals are used in the process, the quantity of undesirable solids is so small that there is no problem involved.

On the other hand, in municipal softening, there may be precipitated with the calcium carbonate an appreciable quantity of other material, depending upon the water and the treatment used.

Mr. Aultman's test data, in carrying out the Estabrook Process, show a furnace product containing as high as 12.6 per cent MgO and 6.7 per cent of inerts. In other words, under these conditions, the desirable calcium oxide byproduct would be only 80.7 per cent of the total reburned material. In other waters, particularly those having a greater magnesium content or a heavier turbidity, the percentage of recoverable lime would be even less.

The Lykkens-Estabrook Process, so thoroughly described in Mr. Aultman's paper, provides an effective method of removing not only magnesium constituents but also inerts. As Mr. Aultman's test data indicate, there may be expected considerable inert material even on waters having such low turbidity as that of the Colorado River following its storage at Boulder Dam. Therefore, provisions for removal of such inerts are especially desirable.

On any new chemical process, experience has indicated that it is exceedingly risky to go directly from laboratory results to large scale installation without extensive pilot plant operation on sufficient scale to prove the process thoroughly. The Boulder City test results show this contention to be correct.

Laboratory tests prior to the Boulder City pilot plant construction indicated the Lykkens-Estabrook Process to be sound and to follow the theoretical reactions of its flow sheet. These laboratory tests did not disclose operating problems which would have to be solved by a large installation but which were uncovered by the worth-while pilot plant work.

It was proved that a build-up of magnesium and inerts can be absolutely prevented by this process and that in general the Lykkens-Estabrook Process is entirely applicable to such lime recovery work. However, as Mr. Aultman has mentioned, the sludge produced in the Primary Clarifier had poor filtering characteristics unless a coagulant was used. Also, there was apparently an unaccounted for lime loss of approximately 21 per cent. Naturally, such operating problems would have been exceedingly serious in a large plant if not solved beforehand.

Results of Various Tests

Tests at Boulder City, treating sludge precipitated by the Estabrook Process, showed the approximate vacuum filtration rate without coagulant to be as low as 68 lb. per sq.ft. per 24 hours. With the use of ferrous sulfate at the point of lime addition, it was possible to increase the filter rate to 194 lb. per sq.ft. per 24 hours.

Samples of this same sludge were sent to the Westport Laboratory of The Dorr Company, Inc., for study. Microscopic examination of this sludge showed it to be more or less made up of very fine crystals of calcium carbonate interspersed with extremely fine solids, presumably magnesium hydroxide. It was the opinion of our laboratory that the material was in a somewhat dispersed condition, with respect to particle size, the bulk of which probably was a little too coarse for good flocculation. This would result in a material of poor filtering characteristics.

Filtration studies were run on this sludge to determine the relative effect of heat and thickening on the filter rates.

The sludge had an initial moisture content of 71.6 per cent. The filtration rate at a temperature of 20°C. was noted. An identical sample was heated to 60°C. and filtered. It was found that the filter rate at 60°C. was 3.55 times that at 20°C. The sludge was then thickened to a moisture content of 66.4 per cent, heated to 60°C. and filtered. The resultant filter rate was 4.83 times the original. The moisture content in the filter cake was only 42.6 per cent.

The gratifying results of these tests have convinced us that the simple expedient of thickening and heating the sludge prior to filtration will give such a material increase in filtration rate that the addition of coagulant will not be necessary. As another adjunct to increasing the filtering rate of the sludge, we suggested carbonation of the sludge from the primary clarifier to produce a change in the

character of the magnesium constituents. No opportunity arose to try such carbonation at Boulder City. However, tests run on a sludge sample from Boulder City by a chemical company specializing in magnesium production, indicated selective carbonation would increase the original filtering rate seven times. We feel it entirely safe to predict that the problem of low filtration rates on sludge produced in the softening of Colorado River water by the Lykkens-Estabrook Process has been solved and that provision for thickening, heating, and carbonation of the primary clarifier sludge would eliminate the previous difficulties on pilot plant operation.

Filter Rates Vary Greatly

It is significant to note that work we have done on filtration of such sludges indicates a wide variation in rates. Filter runs which we made some time ago with a Dorrco Filter, at Marion, Ohio, showed a rate of only about 120 lb. per sq.ft. per 24 hours on a sludge containing 80 to 85 per cent calcium carbonate and from 15 to 20 per cent magnesium hydroxide. Filter leaf tests on sludge from one of the newer mid-western plants average from 175 to 200 lb. per sq.ft. per 24 hours. In this case, alum was also used as a coagulant.

In both of these cases, the lime addition had been made in slurry form, and yet low filtering rates resulted. It appears evident, therefore, that a number of variables determine the filtering rate of water softening sludges and that the use of the clear lime solution of the Estabrook Process may not be altogether responsible for the low rates found in the Boulder City test run. Here again the importance of the pilot plant tests on the rates of filtration of the precipitates formed by the various methods becomes apparent.

In regard to the apparent 21 per cent lime loss unaccounted for in the Estabrook Process, we feel that proper design provisions will permit an almost complete avoidance of such loss.

Tests made on the reaction clarifier sludge, as reported by Mr. Thompson of the Dorr Company indicated a lime content of from 9 to 14 per cent. The difference between these figures and the 21 per cent loss noted is small and may come within experimental error limits.

From the tests on the sludge which indicated the presence of undissolved lime, it is apparent that a considerable quantity dropped out as sludge before it had an opportunity to go into solution.

It is felt that further study on calcination and slaking of the reburned product may result in a product of superior quality. It is possible that improved burning, followed by a classifier and a small mill unit will result in a full dissolution of free CaO. The classifier would remove unburned cores and grit which contribute to poor slaking qualities in lime.

If, after these improvements in the preparation of the reburned lime for re-use, there is still free lime present in the reaction clarifier, a standard washing thickener may be used to wash the clarifier underflow. The thickener effluent, which would ordinarily contain a high percentage of the washed out lime, may be added to the main treatment circuit, and the lime thereby recovered for softening uses.

As the lime reburning end of a caustic soda plant is almost identical to that required in a water softening lime recovery plant, a study of the operating methods of such plants would be helpful to anyone contemplating a recovery of lime from sludge.

Recent data from a lime reburning plant near here indicate that calcination temperatures of from 2,000°F. to 2,300°F. are most effective on their sludge when using a rotary kiln. Burning below 1,900°F. gives poorer results, and there is apparently underburned material discharged with the calcium oxide.

The pioneering work done by the Metropolitan Water District on lime recovery should result in real interest in this method of reducing operating costs by processing a valuable byproduct. The success of their pilot plant operations and the wealth of data obtained are proof of the time and effort spent on the problems by Mr. Aultman and his associates.

Discussion by *Charles P. Hoover*.* Mr. Aultman's paper "Reclamation and Re-use of Lime in Water Softening" is the most comprehensive paper on the subject that has been published thus far in this country. Mr. Aultman has made several conclusions regarding the operation of relatively large lime or lime-soda ash water treatment plants using this process. He states that: (1) a definite saving can be obtained in the cost of lime, (2) a saving will also accrue from the materially smaller amount of sludge to be disposed of, and (3) the byproduct carbon dioxide gas may be used for recarbonation in

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* Chemist in Charge, Water Softening and Purification Works, Columbus, Ohio.

the plant and in this manner effect further savings. If these conclusions are true, then the question is naturally raised "why has not the process been more generally adopted?" At the present time, none of the water softening plants in this country are reclaiming lime.

I think there are five principal reasons why the process has not been adopted: First, as Mr. Aultman has pointed out, most of the larger plants have been built adjacent to sizable waterways into which the sludge can be dumped, and consequently the disposal of sludge has not been of major importance, and lines of least resistance have been followed. Second, most of the larger plants soften and purify river water supplies. The water from most of the streams used is very changeable in its chemical and physical qualities, that is, it changes from clear to turbid water in the course of only a few hours time. The Scioto River, for example, changed on one occasion from a hardness of over 450 p.p.m. and a turbidity of less than 20 to a hardness of 100 p.p.m. and a turbidity of 2,500 p.p.m. in four hours time, and similar changes occur frequently.

Mud Removal Separate from Softening

It is obvious that with an ever changing water the reburning of sludge becomes complicated. With the present type of water softening plant design it would be necessary to shut down the lime burning plant during freshets or following heavy rains because mud mixed with water softening precipitates would, when burned, produce a product with characteristics more like portland cement than lime. With our present knowledge of water softening, however, water softening plants could be designed so that mud removal and softening become two separate operations, and with a plant so designed a lime reclamation plant could be operated continuously. Such a water softening plant would consist of two mixing tanks and two settling basins. In operation the mud would be removed by the use of the first mixing tank and the first settling basin, and the hardness would be reduced in the second mixing tank and the second settling basin. However, the older plants are not so designed, and are not therefore very suitably designed for including the lime reclamation process.

Third, Mr. Aultman has pointed out that the prevention of the accumulation or build-up of magnesium in the reclaimed lime has been a problem which has been solved only very recently, and therefore this magnesium problem has retarded the promotion of the

scheme. Fourth, multiple hearth burners which now seem well adapted for reburning water softening sludge have not been available for this purpose in the past; however, their adoption should add impetus to the lime burning movement. Fifth, small communities usually take their water supply from wells, and although the water is clear and lends itself to a reburning scheme, these communities usually do not wish to embark on a new procedure of this kind. The Miami, Florida, water softening plant is the largest softening plant in this country using well water, and the work done by Mr. Aultman is being closely watched at Miami. Interest is now being manifested in adopting the reclamation process there.

Experience at Columbus, Ohio

In 1914, the city of Columbus planned to reclaim spent lime. It was planned to proceed with the reclamation even in spite of the fact that there was no known process for eliminating magnesium, and with full knowledge of the fact that the operation would have to be intermittent because of mud during flood times. An experimental plant was built, and a little later a full-sized plant was designed. The original estimate of constructing the plant was in the neighborhood of $50,000 to $60,000. The World War was declared shortly after the first experimental work was finished and the price of steel advanced so much that it would have made the project cost an excessive amount. The cost estimate jumped from about $50,000 or $60,000 up to about $150,000.

After the war several things happened: The Marble Cliff Quarry Company built a lime plant about two and a half miles from our plant. This opened up competition and the price of lime dropped $3.00 per ton immediately. During 1932 and 1933 the competition was very keen and less than $4.00 per ton was paid for lime delivered to our plant. In 1925, the O'Shaughnessy Dam was built and this changed the character of our raw water supply. When the water in the reservoir gets muddy, it stays muddy for a month at a time and, of course, the presence of mud in the lime sludge makes it unsuited for burning.

Mr. Aultman, in commenting on the so-called Hoover process, has raised the question as to whether or not good settling would be accomplished following the second application of lime. Laboratory tests indicate that the settling following secondary treatment is very quick. Results obtained in the laboratory indicate that satisfactory

settling is obtained in 9 minutes. Quick settling of magnesium precipitate should, it seems to me, be expected because magnesium precipitated as $Mg(OH)_2$ is an aid to settling. When water containing an appreciable quantity of magnesium is softened with lime, it usually does not need to be coagulated with coagulants such as alum or iron compounds. The floc of magnesium hydroxide produced by lime has the same properties as aluminum and iron hydroxides.

Mr. Aultman has referred to the difficulty encountered in producing a filterable sludge with the Estabrook process, and suggests that a coagulant such as ferrous sulfate be added so as to condition the sludge so that it will be more filterable. It is suggested that perhaps the addition of some slaked lime to the sludge might accomplish the same results as the addition of a coagulant, and as the lime will be reclaimed there would be very little additional expense involved.

Oklahoma City Experience

This suggestion is advanced on the strength of what is being accomplished in Oklahoma City at their water softening plant on the return of sludge to the raw water by way of the slakers. Lime sludge is being returned to the process, but not in the conventional fashion. Sludge is usually returned to the raw water mixing basins along with the water softening reagents. At Oklahoma City sludge is being returned to the lime slakers and used to slake the quick lime. The mixture of sludge and slaked lime is then fed into the raw water at the entrance of the mixing tanks. The lime apparently crystallizes the fine colloidal particles in the sludge so that they settle quickly when the treated water is discharged into the settling basin. If it is not desired to return the sludge directly to the slakers, it may be discharged into a small mixing tank and there mixed with the slaked lime from the slaker, the mixture then being fed into the water.

Mr. Aultman has stated that water softening sludge is sometimes dumped into sizable water ways and carried away without causing an unsightly appearance in the stream, or that it may be lagooned. If a sizable stream is available it affords a very easy and convenient method of getting rid of the sludge, but if no such stream is available the problem may become a very difficult one. It is usually very difficult to find a suitable place near a water plant for lagooning sludge. The places available are usually limited, and consequently an attempt to induce farmers to buy or take away for nothing the accumulated sludge is usually made. In some cases, at smaller

plants, farmers have taken it away without cost to the community. At some few other plants, they have even paid to get it, but at some of the larger plants it has been impossible to get the farmers sufficiently interested in it to move it. The method of applying the air dried sludge to the land is quite simple. It is hauled to the fields and dumped in piles; then about three inches of straw or stable litter is spread on the bottom of the manure spreader, the sludge is then shoveled onto the straw or stable litter and it can then be properly spread over the field.

There are three methods of sludge disposal now available, namely: discharge into streams, lagooning, and reclamation by burning.

It would seem logical that where conditions are favorable reclamation by burning should be used. Now that Mr. Aultman has worked out and presented very complete experimental data and has shown that the process is practical and economical, it is hoped that in the near future a full-sized plant will be built. With precedent to follow there is no doubt that the process will become widespread in its use.

Short Schools and Operator Qualifications

By Charles R. Cox

INVESTIGATION of outbreaks of water-borne diseases has definitely indicated that there is a marked change in their character, in that they are now seldom due to the use of untreated polluted water or to improperly designed water purification equipment, but that recent outbreaks are due to: (a) cross-connections between potable and non-potable supplies; (b) to abnormal conditions developing suddenly during periods of drought or flood; or (c) to failure to operate properly water supply systems and purification works. In other words, failures in supervision or operation are of paramount importance.

One seldom stops to consider the duties confronting the average superintendent in charge of a water supply system or the extensive training necessary for the prompt and efficient exercise of such duties. A great deal of the training required in the operation of a water supply system can be secured only by experience. On the other hand, an adequate technical training is of fundamental importance but this cannot be expected of those in charge of the smaller supplies as long as the prevailing small salaries continue. The successful operation of water supply systems, therefore, requires that competent operators be encouraged to improve their ability and that they be protected from discharge for political motives.

A very brief review of the water supply statistics for New York State will indicate the magnitude of the problems of operation:

There are 769 public water supplies in New York State, 392 of which are secured from wells or springs, the remaining being secured from surface sources, although 49 supplies are secured from both ground water and surface sources. Due to the generally satisfactory

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A paper presented at the New York Section meeting at Poughkeepsie, New York, September 22, 1938, by Charles R. Cox, Chief, Bureau of Water Supply, New York State Dept. of Health, Albany, N. Y.

quality of the ground water used so extensively in the state, it is not surprising that only 379 of the 769 supplies are subject to treatment. As might be expected, treatment by chlorination alone predominates, there being 240 chlorinated supplies. Mechanical filtration and chlorination are practiced at 107 supplies, whereas slow sand filters and chlorination are used for the treatment of 25 supplies. The remaining 7 supplies are subject to treatment by filtration without chlorination. It is significant to note that because of the very small size of many of these untreated supplies, over 11 million of the total 13 million population of New York State are served by public water supplies subject to treatment.

The present status of supervision may be of interest in connection with this discussion. As far as our records indicate, practically all supplies serving municipalities with populations over 20,000 are supervised by graduate engineers or chemists, and that about 50 of the supplies of municipalities with populations of 5,000 to 20,000 are so supervised. Such supervision is indirect in many cases, as when superintendents of public works are the direct superiors of water treatment plant operators. Thus 17 of 96 supplies serving populations over 5,000 are managed in this manner. This has a direct bearing on the classification of operators, as discussed below. Most of the smaller supplies are supervised by part time superintendents of water, who are the operators of any treatment works utilized.

Laboratory Control in New York State

Ninety-five of the public supplies are subject to local laboratory control by water officials including a number of untreated supplies from wells. The local health departments of some of the larger communities also examine samples of water at daily intervals. Furthermore, consulting chemists supervise 37 supplies. In addition, the laboratories of 30 counties are examining samples at monthly intervals from 260 of the supplies in these counties. Finally, the State Department of Health examines about 5,000 samples each year from all of the supplies in the state, the frequency of sampling being 4 to 24 times per year depending upon local conditions and the degree of treatment, if any.

Since the Division of Sanitation was organized in 1906, routine inspection of the public water supply systems has been maintained. This is now greatly facilitated through the organization of 20 district

offices whereby more intimate supervision is possible. In addition, water purification specialists are available from the central office to assist in solving problems of operation and to instruct operators lacking technical training in laboratory control procedures. This routine supervisory work, while of fundamental importance, was found to be inadequate, so water works schools were organized in 1931 to provide an opportunity for operators to confer with each other and take part in an intensive training program. Each of the schools held in 1931 and 1934 in Albany was attended by over 100 operators. It became evident that the attendance could be materially increased were regional schools organized so as to reduce the time and expense of traveling. For this reason, the 1936 school was decentralized and conducted at Syracuse University, in the State Office Building in Buffalo and at Poughkeepsie. The regional schools held in the spring of 1938 were conducted at Cornell University, at New York University and at Rensselaer Polytechnic Institute. The holding of the regional schools has about trebled the total attendance.

Limitations of the Short Schools

In the past, it has been necessary to restrict the schools to periods of four days and for instructions to be given by lecturers covering the fundamental subjects of sources of water supplies and the operation of treatment plants, especially chlorination plants. It was impossible, however, to impart detailed knowledge as to the operation of filtration plants nor were facilities available for training in laboratory procedure. The short schools heretofore held, however, have been found adequate for the training of Grade III operators to be discussed below, where treatment by chlorination alone is involved.

Because of the necessary limitations in the type and degree of training possible at the short schools, it has been found necessary to plan more intensive types of schools for Grade II operators interested in filtration plants, where instruction in laboratory procedures would be possible. The necessity of restricting the number of students to those who can be accommodated by available laboratory facilities at the schools makes it impossible to have more than about ten students at each school. This, of course, will require restrictions as to those who attend. Generally speaking, first preference must be given to those operators who must receive training at these schools to enable them to qualify as Grade II operators in charge of filtration

plants. It is planned to continue holding the short schools of four days duration at intervals of every two years.

The evident necessity of having water purification plants controlled by properly qualified operators, led the Public Health Council in 1937 to amend Chapter XI of the State Sanitary Code appended hereto, whereby the qualifications of operators of water purification plants are defined in terms of experience and training.

Before discussing these requirements, it is very essential to indicate that this portion of the Code does not apply to those in charge of water supplies not subject to treatment, or to operators of water purification plants operated by water companies, but is restricted to the operators of municipally owned water purification plants. Furthermore, the requirements do not apply to operators employed prior to October 1, 1937.

Three Grades of Operators Described

The code classifies operators into three grades, depending upon the type of treatment and the population served by the water supply systems under their supervision. Grade I operators are those in charge of the operation of any type of treatment plants serving populations greater than 20,000, or the operators of filtration plants serving populations greater than 10,000. This means that the operators of chlorination plants serving populations greater than 20,000 would have to meet the requirements of Grade I operators.

Grade II operators, on the other hand, are those in charge of the operation of any water treatment plants, excepting filtration processes, serving populations of from 5,000 to 20,000 or those in charge of filtration plants serving populations less than 10,000, or the operators employed at filtration plants under the supervision of Grade I operators.

Grade III operators are those in charge of any water treatment plants not employing filtration processes and serving populations of less than 5,000 or the operators acting under the general supervision of Grade II operators. In other words, operators of chlorination plants treating supplies serving populations less than 5,000, or the shift operators employed at filtration plants under the supervision of Grade II operators would have to meet the qualifications for Grade III operators.

In general, subordinate operators must meet the qualifications one grade below their supervising operator. A few examples might

be of interest in clarifying the above statements. For instance, the filtration plant of a city of 12,000 population is under the personal supervision of the city engineer, even though the details of control are in charge of the chief operator. In this instance the city engineer is classified by training and duties as Grade I operator, and the chief operator is classified as Grade II operator. In another city, however, the superintendent of water exercises only general supervision over the filtration plant, and the chief operator is in responsible charge, and thus must qualify as a Grade I operator. The same principles are illustrated by the situation in another large city where the superintendent of water, a Grade I operator, is in responsible charge of the operation of the chlorination plants, supervising the work of the Grade II shift operators.

Experience and Training of Operators

The qualifications for the above three grades of operators have been based upon the combination of experience and training. The qualifications for a Grade I operator briefly are as follows: Graduation from a technical school plus at least one year of experience at a water treatment plant, or one who has completed a course of instruction in water purification approved by the Public Health Council, provided that he has had at least five years experience at a water treatment plant, or any combination of training and experience acceptable to the Public Health Council. In general, these qualifications rule out those lacking training at technical schools, as there is little likelihood that the Public Health Council will approve short schools as meeting the special training requirements for Grade I operators.

The qualifications for Grade II operators require graduation from a high school plus instruction in water purification approved by the Public Health Council, such as the two weeks duration schools mentioned above, provided the operator has had at least one year's experience at a water treatment plant. In lieu of a high school training, the requirements are modified by requiring at least three years experience, provided the operator has attended one of the more advanced water works schools. Here again the Public Health Council may accept in lieu of the above any combination of training and experience.

The qualifications for Grade III operators disregard education, but require at least one year's experience at a water treatment plant

and the completion of a course of instruction in water purification approved by the Public Health Council, such as the four day duration short schools discussed above.

Operators of water purification plants employed since October 1, 1937 must submit evidence as to their qualifications on blanks obtained from the Department. Under special circumstances, the Public Health Council may waive the requirements in any grade as to operators proposed for appointment, but not for a period longer than the term of the proposed appointment. The Council may require an operator receiving such a waiver to take such examinations as may be directed and the operator is also expected to attend the water works school.

The revised Sanitary Code definitely considers water purification and sewage treatment plant operators to be engaged in the field of public health. So they are classified as public health personnel. The provisions of the Code, however, do not include licensing as in the case of some other state laws, but "Certificates of Qualification" are to be issued.

Grandfather's Clause Limited

As stated above, there is a "grandfather's clause" in the Code which exempts operators employed before October 1, 1937. This exemption, however, applies only when the operator remains at the same treatment plant, so the qualifications would have to be met if a change in employment is involved.

Exempt operators may apply for a certificate of qualification if they so desire, but such would not be issued unless the qualifications as to training and experience are actually met.

In many instances the present exempt operators will not be able to qualify as to the grade in which they are actually employed, and thus cannot receive a certificate of qualification. This may cause embarrassment and disappointment, and may lead to a feeling that the qualifications are too rigid. The purpose, however, is to elevate the status of operators, especially those employed in the future. The present operators being exempt from these requirements are encouraged to improve their training so that they may be able to meet the qualifications at some later date. In the meantime, they are protected in that they cannot be replaced except by those meeting the qualifications.

It is the desire of the Department to endeavor in every way possible

to protect the properly qualified operators of water treatment plants and to facilitate the further training of those lacking a formal technical education. A realistic approach to the problems will be maintained to avoid arbitrary action and to insure that all factors governing the qualifications of specific operators will be viewed in the light of the local conditions at the treatment plants under their supervision. It is believed that in this way the status of the operators will be elevated to a point where the public and municipal officials will realize more forcefully the importance of the duties in question, which in turn will lead eventually to more adequate salaries and stabilized employment. The net results of course will be improved water supply systems.

QUALIFICATIONS OF OPERATORS OF PUBLIC WATER TREATMENT AND PURIFICATION PLANTS

THE SANITARY CODE

Enacted by

The Public Health Council of the State of New York

(Adopted September 24, 1937)

CHAPTER XI

Qualifications of Public Health Personnel

SECTION E—OPERATORS OF PUBLIC WATER TREATMENT AND PURIFICATION PLANTS

Regulation 35. Definition. The term "operator" as used in this section shall mean any individual who is paid from public funds and who is employed or appointed by any county, city, village, town or district, or by any state department as the person in charge of the operation of any water treatment or purification plant or essential part thereof.

Regulation 36. Qualifications required. No person shall be appointed hereafter as operator unless he shall possess at the time of appointment the qualifications hereinafter prescribed for such position, except that this requirement shall not apply to operators employed prior to October 1, 1937, nor to operators appointed to positions from civil service lists established prior to October 1, 1937.

Regulation 37. Preliminary qualifications. An operator shall be physically capable of performing his duties, able to read, write, make simple arithmetical computations and shall produce evidence acceptable to the appointing authority as to his character and his ability to maintain and operate properly all equipment entrusted to his care.

Regulation 38. Grades established. There are hereby established qualifications for operators in three grades to be known as Grade I, Grade II, and Grade III.

Grade I. The following operators shall have the qualifications prescribed for Grade I:

(1) Operators responsible for or in charge of the operation of any water treatment or purification plant supplying water to a population of more than 20,000; or,

(2) Operators responsible for or in charge of the operation of any water purification plant employing a filtration process and supplying water to a population of more than 10,000.

Grade II. The following operators shall have the qualifications prescribed for Grade II:

(1) Operators responsible for or in charge of the operation of any water treatment plant not employing a filtration process and supplying water to a population of from 5,000 to 20,000; or,

(2) Operators responsible for or in charge of the operation of any water purification plant employing a filtration process and supplying water to a populaton of less than 10,000; or,

(3) Operators acting under general supervision in plants required to be under the charge of Grade I operators.

Grade III. The following operators shall have the qualifications prescribed for Grade III:

(1) Operators of any water treatment plant not employing a filtration process and supplying water to a population of less than 5,000; or,

(2) Operators acting under general supervision in plants required to be under the charge of Grade II operators.

Nothing herein shall be construed to prevent the employment or appointment of an operator in a grade lower than that for which he is qualified.

Regulation 39. Qualifications, Grade I. The qualifications for operators in Grade I shall be practical experience and special training and education in water purification or treatment, consisting of:

(a) Graduation from a university or school of recognized standing with a degree in public health, sanitary, chemical, or civil engineering, provided that graduates in chemical or civil engineering shall have completed acceptable courses in sanitation; and, provided that all shall have had not less than one year of satisfactory experience in a water purification or treatment plant; or,

(b) Completion of a course of instruction in water purification or treatment approved by the public health council as qualifying for this grade, provided that such persons shall have had not less than five years of satisfactory experience in a water purification or treatment plant; or,

(c) Any combination of education, training, and experience which in the opinion of the public health council is the equivalent of either of the above qualifications.

Regulation 40. Qualifications, Grade II. The qualifications for operators in Grade II shall be practical experience and special training and education in water purification or treatment, consisting of:

(a) Graduation from a high school and completion of a course of instruction

in water purification or treatment approved by the public health council as qualifying for this grade, provided that such persons shall have had not less than one year of satisfactory experience in a water purification or treatment plant; or,

(b) Completion of a course of instruction in water purification or treatment approved by the public health council as qualifying for this grade, provided that such persons shall have had not less than three years of satisfactory experience in a water purification or treatment plant; or,

(c) Any combination of education, training, and experience which in the opinion of the public health council is the equivalent of either of the above qualifications.

Regulation 41. Qualifications, Grade III. The qualifications for operators in Grade III shall be practical experience and/or special training and education in water purification or treatment, consisting of:

(a) Not less than one year of satisfactory experience in a water purification or treatment plant; or,

(b) Completion of a course of instruction in water purification or treatment approved by the public health council as qualifying for this grade, provided that such persons shall have had not less than three months of satisfactory experience in a water purification or treatmenr plant; or,

(c) Any combination of education, training and experience which in the opinion of the public health council is the equivalent of either of the above qualifications.

Regulation 42. Submission of evidence of qualifications. Any person may submit evidence of his qualifications, or any appointing authority may submit evidence of the qualifications of any person, to the public health council for opinion as to whether or not such person meets the qualifications for operators in a specified grade.

Regulation 43. Authority to waive requirements or to require examinations. The public health council may, under special circumstances specified by the local appointing authority or by the proposed operator, waive the requirements in any grade as to any proposed appointment, such waiver to be valid for such period as may be specified by the public health council but not for a period longer than the term of the proposed appointment. The public health council may require any person, whose qualifications it is called upon to consider, to take such written, oral, or practical examination as it may direct.

Regulation 44. When to take effect. Every regulation in this section shall take effect on October 1, 1937.

Studies on Media for Coliform Organisms

By C. W. Darby and W. L. Mallmann

THERE has been considerable doubt in the minds of the writers as to the value of standard lactose broth as an enrichment medium for culturing coliform organisms from water and other sources when the organisms have been attenuated or when they appeared in minimal numbers. The fact that coliform organisms frequently appear in fermentation tubes after incubation periods longer than 48 hours or in tubes incubated at temperatures below 37°C. would seem to indicate that the prolonged lag phase of growth might be caused by an unfavorable environment in the nutrient medium. Little effort has been made to check the efficiency of this medium by the development of better enrichment media for comparative tests. More frequently this medium has been used as a standard to measure the value of new selective media in an attempt to produce a new medium with selected properties for the coliform organism with enrichment value equal to that of the present standard lactose broth.

The appearance on the market of new peptones which are being used extensively in the growth of such pathogenic bacteria as the diphtheria bacillus and gonococcus offers an opportunity for the application of these nutrients to the growth of other organisms such as the coliform group. In this laboratory Bacto-tryptose, a peptone, which is being used extensively for the cultivation of organisms that grow scantily on Bacto-peptone media, seems particularly adaptable to this application.

In most studies on the elaboration of a nutrient medium it has been customary to measure the response of the organisms to the medium by using a loopful of organisms to each tube of material

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tested and then measuring the maximum growth obtained at the end of 24 to 48 hours incubation. The medium giving the greatest amount of growth at this time has been selected as the best. In most instances, perhaps, this procedure has obtained its end, particularly if the investigator desires large quantities of organisms.

It is the authors' contention, however, that the medium giving the greatest number of organisms in 24 or 48 hours incubation is not necessarily the best diagnostic medium. It would seem that the best diagnostic medium is one that will allow the development of the desired organism when minimal numbers are present in the material to be examined. In waters of questionable sanitary quality it is conceivable that the use of standard lactose broth may not obtain such results.

TABLE 1

Viability of Esch. Coli in Different Media Before and After Lethal Exposure to Irradiation

MEDIA	UNTREATED	IRRADIATED	HEATED
Nutrient agar	570,000	20	27
Nutrient agar/blood	570,000	65	102
Nutrient agar/glucose	600,000	45	105
Nutrient agar/yeast	610,000	25	27
Infusion agar	610,000	38	189
Tomato juice milk powder agar	540,000	69	237

It is not within the province of this paper to show the practical significance of the increasing numbers obtained but it is our thesis that a diagnostic medium should produce a maximum number of the organisms present from the material examined whether it be the diphtheria bacillus from a throat swab or coliform organisms from a water supply. The value of a diagnostic medium lies in those of its properties which promote a rapid growth of the dormant viable cells in the material examined. There should be a continuance of rapid reproduction until the cells appear in such abundance that they can be recognized by their physiological action on the medium or so that they can be transplanted to differential media.

Many media do not present a suitable environment for the viable cells to reach the reproductive stages and thus fail to give positive cultures. Many viable cells of *Escherichia coli* fail to reproduce on certain media as shown by Curran and Evans (2) in table 1. It will

be observed from this table that on the tomato juice milk powder agar 237 cells survived heat treatment; whereas on the nutrient agar only 27 cells survived. That the latter medium is best suited for demonstrating surviving organisms is quite apparent.

It is a well established fact that when organisms are transferred from one environment to another, particularly if the new environment differs radically from the previous one, many viable cells fail to reproduce due to their inability to adjust themselves to the new conditions or to adjust their immediate surroundings to their needs. Because of this it is customary in transferring many organisms to use mass seedings, hoping that a sufficient number of viable cells will reproduce and thus assure a positive culture.

In single-cell isolation work Wright and Hendrickson (20) found that by incubating the single cell in a drop of broth in a moist chamber, rather than in a tube of nutrient medium, they were able to grow as high as 90 per cent of the cells isolated. It would appear from this work that the cell must adjust its environment to its own needs and that by the use of a minimum rather than a large volume of broth the cell is able to adjust itself more rapidly and more surely. A number of years ago, the junior author of this paper spent several months trying to single-cell several strains of *Salmonella pullorum* using many types of enrichment media without success. Then one night in a demonstration of single-cell culture, five out of six cells grew in plain nutrient broth. Following this discovery, using the same batch of medium, single-cell cultures were prepared for all the desired strains of *Sal. pullorum* with a very high percentage of the single-cells growing. No explanation was found as to why this particular batch of medium gave results when previous batches and other media failed. But it appears quite obvious that environmental conditions were such that each viable single cell found its surroundings conducive to immediate growth without considerable adjustment prior to reproduction.

Reproduction begins after a cell has overcome its stationary phase and has taken in sufficient food material. As soon as the cell has undergone fission the resulting two young cells begin growth and ultimately reproduction. A new critical period in the life of the organism begins with the completion of fission. The work of Salter (11), Schultz and Ritz (12), Reichenbach (10), Sherman and Albus (13, 14), Stark and Stark (17), Heiberg (4), and Sherman and Cameron (15) shows that young cells are much more susceptible to

adverse conditions such as heat, 2 per cent sodium chloride, 0.5 per cent phenol, and dilute crystal violet, than cells found in the lag stages of a logarithmic growth phase. Huntington and Winslow (6) show that during the lag stage and the early logarithmic stage of growth the young cells exhibit all the characteristics of physiological youth comparable to those exhibited in multi-cellular organisms. This means that a good medium must produce an environment such that no inimical conditions exist during the critical period of lag and early logarithmic stages of growth. Otherwise the mortality of the cells may be such that no growth results.

It is our thesis in the light of past experience and the studies cited that a culture medium for diagnostic use should be measured not by gross growth obtained at the completion of the logarithmic stage

TABLE 2

Influence of Bacto-peptone in Various Concentrations in the Base Medium on Lag Phase of Growth of Esch. Coli, No. 161*

CONCENTRATION OF BACTO-PEPTONE	NUMBER OF BACTERIA PER ML.					
	Initial	4 hours	6 hours	12 hours	24 hours	48 hours
per cent						
0.5	15	800	2,900	52,000,000	413,000,000	408,000,000
1.0	20	1,200	4,700	30,000,000	704,000,000	731,000,000
2.0	18	1,260	4,400	32,000,000	1,300,000,000	872,000,000
3.0	16	770	1,750	8,300,000	1,940,000,000	1,244,000,000

* Base medium consists of: Bacto-beef extract 0.3 per cent, lactose 0.5 per cent.

but by the behavior of the organism during the lag and early logarithmic stages of growth. Therefore in the studies presented we have worked with minimal numbers of organisms that have been attenuated by age and we have studied the behavior of these organisms primarily during the lag and early logarithmic growth stages.

Procedure

Growth rates were determined in broth media containing various concentrations of the ingredients that enter into a nutrient medium to ascertain the amounts giving the maximum rate of reproduction during the early stages of the logarithmic growth phase of the organism. For these studies a laboratory strain of *Esch. coli* (No. 161)

was selected. This culture was kept on an agar slant and, after the full development of the culture, it was kept in the refrigerator. Storage in the refrigerator over a period of months tended to attenuate the culture sufficiently to increase the stationary phase of the organism and thus give a better picture of the value of the medium studied in the recovery of the viable cells present. In all experiments organisms were taken directly from these slant cultures and introduced directly into the medium under investigation.

Small seedings were used to intensify the difficulties of the organisms to overcome unsuitable environments and thus increase the marginal differences in growth rates of the different types of media used.

Considerable care was exercised in the preparation of the media and in the technics of growing the cultures and the determinations of the numbers present in order to eliminate as far as possible all variables other than the one variable under study.

Experimental Background

Peptone. In an earlier study of bacteriostatic action of dyes, it was observed (table 2) that a concentration of 3 per cent Bacto-peptone in a medium caused a decreased growth in the lag phase of growth of *Esch. coli.* The fact that this concentration acted as an inhibitory agent seemed to indicate that a concentration of 0.5 to 1 per cent was best, not because the organisms grew best at these concentrations, but that in more dilute amounts it was less toxic. It would appear that its use in an enrichment medium such as lactose peptone broth certainly would not favor the development of isolated cells or groups of cells that were partially attenuated by chlorination. It appears quite evident that a more satisfactory source of nitrogenous food should be found.

A comparison of Bacto-tryptose and Bacto-peptone showed that much more rapid growth occurred with the former peptone (table 3). The two media are not exactly comparable because the constituents and their concentrations differ; however, the medium containing the Bacto-tryptose was far superior at all stages of growth through a 12-hour incubation period. The data are presented to show the marked difference between the two media.

The most effective concentration of tryptose was determined by varying the amounts of tryptose from 1 to 3 per cent in the same base medium. In table 4 data are presented for growth rates of

Esch. coli in varying concentrations of tryptose in a base medium of 2 per cent bile brilliant green lactose broth while for the growth rates in table 5 a phosphate buffered medium was used. In the bile brilliant green medium, 3 per cent tryptose gave the most rapid growth while in the buffered medium there was little choice between 2 and 3 per cent tryptose, although the 2 per cent medium showed slightly higher rates of growth. In similar experiments 2 and 3 per cent tryptose showed about the same effect on growth rates, although in general the 3 per cent concentration appeared to be slightly the better medium. In concentrations up to 4 per cent, the highest concentration tested, Bacto-tryptose showed no inhibitory effect such as that observed with Bacto-peptone.

TABLE 3

Comparison of Bacto-peptone and Bacto-tryptose Media by Means of Growth Rates of Esch. Coli, No. 161

MEDIUM	NUMBER OF BACTERIA PER ML.				
	Initial	3 hours	6 hours	9 hours	12 hours
Lactose broth*	86	1,560	573,000	31,300,000	232,000,000
Tryptose broth†	97	5,300	12,700,000	585,000,000	1,050,000,000

* Lactose broth: dehydrated Difco lactose broth.

† Tryptose broth: Bacto-tryptose 3.0 per cent, lactose 0.5 per cent, NaCl 0.5 per cent.

The concentration of 2 per cent was selected as optimum as the increased activity induced by 3 per cent tryptose did not appear to warrant the additional expense involved in practical use of the medium. It is possible that in practical applications, a one per cent concentration may be satisfactory.

Hydrogen ion concentration. Although the pH range for the growth of *Esch. coli* appears to be quite wide, it was felt that the influence of pH should be carefully checked to determine the effect on early growth rates. Media consisting of 3 per cent Bacto-tryptose and 0.5 per cent lactose were adjusted to pH values of 6.8, 7.0, 7.2, 7.4, 7.6, and 7.8 and tested as in previous experiments. No pH values below 6.8 were tested as acid will cause a hydrolysis of the lactose during sterilization. The results are presented in table 6. It should be observed that at the end of 6 hours incubation at pH 6.8 the number of organisms was nearly double the number at

TABLE 4

Influence of Bacto-tryptose in Various Concentrations in a 2 per cent Brilliant Green Lactose Broth Base Medium on Lag Phase of Growth of Esch. coli, No. 161*

CONCENTRATION OF BACTO-TRYPTOSE	pH	NUMBER OF BACTERIA PER ML.								
		Initial	2 hours	3 hours	4 hours	6 hours	8 hours	12 hours	24 hours	48 hours
per cent										
1.0	7.4	30	55	700	850	11,130	302,000	205,000,000	600,000,000	86,000,000
2.0	7.4	33	62	904	2,450	17,000	869,000	398,000,000	980,000,000	95,000,000
3.0	7.4	36	52	1,380	4,800	36,100	2,444,000	839,000,000	1,420,000,000	132,000,000
Standard 2 per cent bile—B. G. broth Difco		33	37	470	530	6,200	133,000	78,000,000	440,000,000	33,000,000

* Base medium consists of: Bacto-ox-bile 2 per cent, brilliant green 0.00133 per cent, lactose 0.5 per cent.

TABLE 5

Influence of Bacto-tryptose in Various Concentrations in the Base Medium on Lag Phase of Growth of Esch. Coli, No. 161*

CONCENTRATION OF BACTO-TRYPTOSE	SAMPLE	NUMBER OF BACTERIA PER ML.			
		Initial	3 hours	6 hours	12 hours
per cent					
1	1	84	3,800	333,000	1,330,000,000
	2	86	3,300	397,000	995,000,000
	3	88	2,700	402,000	1,150,000,000
	Average	86	3,300	377,000	1,158,000,000
2	1	102	4,500	1,712,000	1,760,000,000
	2	90	3,600	646,000	1,450,000,000
	3	89	3,400	1,144,000	1,510,000,000
	Average	94	3,800	1,168,000	1,587,000,000
3	1	78	2,000	1,262,000	1,950,000,000
	2	96	2,900	994,000	2,000,000,000
	3	79	3,700	1,400,000	1,780,000,000
	Average	84	2,900	1,218,000	1,953,000,000

* Base medium consists of: lactose 0.5 per cent; K_2HPO_4 0.4 per cent; KH_2PO_4 0.15 per cent; NaCl 0.5 per cent; adjusted to pH 6.8 before sterilization.

pH 7.0 and that at increasing pH values the amount of growth decreased until at pH 7.8 the growth was only approximately one-fourth that obtained at pH 6.8.

In a number of other similar experiments, the maximum growth appeared at pH 6.8 during the early periods of the lag phase of growth. It will also be observed from these data that with the higher pH values, greater amounts of growth appeared at 24 and 48 hours incubation. This would be expected as the limiting acid concentrations caused by the fermentation of the lactose would be approached sooner in the growth cycle of the organisms in the media which were adjusted to lower pH values. A reaction of pH 6.8 was selected as the optimum value for the growth of *Esch. coli.*

TABLE 6

Influence of the Hydrogen Ion Concentration of lactose-bacto-tryptose Broth on Lag Phase of Growth of Esch. Coli, No. 161*

pH	NUMBER OF BACTERIA PER ML.				
	Initial	6 hours	12 hours	24 hours	48 hours
6.8	38	31,800	182,000,000	920,000,000	880,000,000
7.0	35	17,800	177,000,000	1,150,000,000	1,670,000,000
7.2	41	17,200	229,000,000	1,218,000,000	1,040,000,000
7.4	30	14,100	185,000,000	1,250,000,000	1,428,000,000
7.6	31	8,800	240,000,000	1,993,000,000	2,510,000,000
7.8	35	7,900	281,000,000	2,015,000,000	2,630,000,000

* The base medium consists of: Bacto-tryptose 3 per cent and lactose 0.5 per cent.

Walker and Winslow (19), Mallmann and Gallo (7), Slanetz and Rettger (16), and others have demonstrated that the addition of a phosphate buffer to a medium caused an increase in the total number of bacteria produced as compared to a similar medium without buffer. The use of buffered media for fermentation experiments was suggested by Bronfenbrenner and Schlesinger (1). The increased number of bacteria was believed by Mallmann and Gallo (7) to be due not only to the buffering effect on the acid produced by the organisms, but also to the need of phosphate in the metabolism of the organisms. The use of a buffered lactose peptone broth as a presumptive medium for the coliform organisms was recommended by Thompson (18).

In a study of buffers, Perry and Hajna (9) recommended a buffer mixture of 0.4 per cent K_2HPO_4 and 0.15 per cent KH_2PO_4 for the growth of coliform organisms. As these amounts give a pH of 6.8 in the medium before sterilization, this mixture was used. In all instances where the pH values were other than 6.8, the medium was adjusted to this value by the addition of normal NaOH. In table 7, the data for three series of these tests are presented. It will be observed that in all instances the growth during the early stages of reproduction and the later stages of the logarithmic phase, was much greater for the buffered medium. In media prepared by the Difco Laboratories, there was little choice between the buffered and non-buffered media during the early growth period but in most instances in the late logarithmic phase the buffered medium was superior. In general, the data showed that the addition of a buffer to the medium,

TABLE 7

Influence of a Buffer Mixture in the Base Medium on the Lag Phase of Growth of Esch. Coli, No. 161*

BUFFER	pH	SERIES NO. 1				
		Number of bacteria per ml.				
		Initial	6 hours	12 hours	24 hours	48 hours
None	7.0	35	17,800	177,000,000	1,150,000,000	1,670,000,000
Present	7.0	32	81,100	578,000,000	1,850,000,000	2,790,000,000
		SERIES NO. 2				
		Initial	3 hours	6 hours	9 hours	12 hours
None	6.8	19	725	1,217,000	470,000,000	997,500,000
Present	6.8	16	890	3,362,000	840,000,000	1,555,000,000
		SERIES NO. 3				
		Initial	2 hours	4 hours	6 hours	8 hours
None	6.8	95	350	28,700	2,050,000	88,200,000
Present	6.8	108	430	40,700	2,570,000	139,700,000

* Buffer mixture: K_2HPO_4 0.4 per cent; KH_2PO_4 0.15 per cent.

Series No. 1, base medium: Bacto-tryptose 3.0 per cent, lactose 0.5 per cent.

Series No. 2, base medium: Bacto-tryptose 2.0 per cent, lactose 0.5 per cent, NaCl 0.5 per cent.

Series No. 3, base medium: same as No. 2.

although not always causing an increase in reproduction during the early stages, did not hinder the rate of growth and in the late stages of the logarithmic phase the buffer caused a marked increase in the number of organisms.

TABLE 8

Influence of Sodium Chloride in a Base Medium on the Lag Phase of Growth of Esch. Coli, No. 161*

CONCENTRATION OF NaCl	BUFFERED MEDIUM*				
	Number of bacteria per ml.				
	Initial	6 hours	12 hours	24 hours	48 hours
per cent					
None	32	81,100	578,000,000	1,850,000,000	2,790,000,000
0.5	35	106,000	1,068,000,000	2,500,000,000	1,970,000,000
	NON-BUFFERED MEDIUM†				
None	35	17,800	177,000,000	1,150,000,000	1,670,000,000
0.5	39	67,000	535,000,000	1,755,000,000	1,610,000,000

* Base medium consists of: Bacto-tryptose 3 per cent, lactose 0.5 per cent, K_2HPO_4 0.4 per cent; KH_2PO_4 0.15 per cent.

† Base medium consists of: Bacto-tryptose 3 per cent, lactose 0.5 per cent.

TABLE 9

Influence of Sodium Chloride in the Base Medium on the Lag Phase of Growth of Esch. Coli, No. 161*

CONCENTRATION OF NaCl	pH	NUMBER OF BACTERIA PER ML.				
		Initial	2 hours	4 hours	6 hours	8 hours
per cent						
0.5	6.8	108	430	40,700	2,570,000	139,700,000
1.0	6.8	90	540	53,100	2,090,000	153,200,000
2.0	6.8	109	250	20,600	650,000	42,000,000

* Base medium consists of: Bacto-tryptose 2 per cent, lactose 0.5 per cent, K_2HPO_4 0.4 per cent, KH_2PO_4 0.15 per cent.

Sodium Chloride. Dunham (3) reports that the addition of sodium chloride to eosin-methylene blue medium causes a marked increase in the number of positive coliform organisms isolated from lactose presumptive tubes showing gas. Mooney and Winslow (8) observed that *Salmonella pullorum* would not grow in peptone-glucose broth medium when aerated but when 0.5 per cent NaCl was added, growth was rapid. For these reasons the influence of NaCl was tested for

the development of the coliform organisms in a tryptose medium. In table 8 the data on the effect of 0.5 per cent NaCl in both a buffered and non-buffered medium are presented. It will be observed that in both media the addition of NaCl caused a marked increase in growth both in the early stages of growth and even in the decreasing logarithmic phase. In table 9 data showing the effect of 0.5, 1.0, and 2.0 per cent NaCl in a medium are presented. There was little difference between 0.5 and 1.0 per cent but 2.0 per cent showed a marked inhibitory effect on the rate of growth at

TABLE 10

Influence of Lactose in the Basic Medium on Lag Phase of Growth of Esch. Coli, No. 161*

CONCENTRATION OF LACTOSE	SAMPLE	NUMBER OF BACTERIA PER ML.				
		Initial	2 hours	4 hours	6 hours	8 hours
per cent						
0.25	1	86	240	8,220	626,000	78,000,000
	2	97	240	7,200	804,000	52,500,000
	Average	91	240	7,710	715,000	65,250,000
0.5	1	95	230	7,000	558,000	70,000,000
	2	108	250	9,400	470,000	66,300,000
	Average	102	240	8,200	514,000	68,300,000
1.0	1	92	220	9,400	640,000	53,800,000
	2	100	280	9,100	710,000	82,000,000
	Average	96	250	9,250	675,000	67,900,000
2.0	1	86	250	9,200	404,000	30,500,000
	2	97	240	8,150	506,000	36,200,000
	Average	91	245	8,675	455,000	33,350,000

* Basic medium consists of: Bacto-tryptose 2 per cent, NaCl 0.5 per cent, KH_2PO_4 0.15 per cent, K_2HPO_4 0.4 per cent; pH 6.8 before sterilization.

all stages of the logarithmic phase up to 8 hours incubation. In the light of these data, the addition of 0.5 per cent NaCl seemed advisable.

Lactose. Hershey and Bronfenbrenner (5) found that a concentration of 3.0 per cent lactose in a synthetic medium encouraged greater production of carbon dioxide and growth of slow lactose-fermenting organism than did a concentration of 0.5 per cent. To determine the influence of the concentration of lactose an experiment was set up using 0.25, 0.5, 1.0, and 2.0 per cent lactose. The

results are presented in table 10. No difference was observed in the rate of growth for concentrations of 0.25, 0.5 and 1.0 per cent lactose. With 2.0 per cent lactose a decrease in growth was evident after 4 hours incubation.

Mallmann and Gallo (7) found that *Esch. coli* even in a buffered medium seldom utilizes more than 0.5 per cent glucose and seldom more than 0.3 per cent in an unbuffered peptone broth. Inasmuch as no difference was found in concentrations varying from 0.25 to 1.0 per cent and because actual utilization of lactose is generally not more than 0.5 per cent, there appeared no reason for a change from the present accepted concentration.

TABLE 11

*Comparative Growth Rates of Strains of Escherichia coli and Aerobacter aerogenes on Tryptose lactose Broth**

CULTURE	NUMBER OF BACTERIA PER ML.			
	Initial	4 hours	8 hours	12 hours
Esch. coli—161	72	44,200	92,000,000	1,400,000,000
Esch. coli—165	211	16,500	37,000,000	990,000,000
Esch. coli—166	207	58,000	28,000,000	1,430,000,000
Esch. coli—171	253	41,900	74,000,000	1,100,000,000
Aer. aerogenes—140	225	24,400	20,160,000	740,000,000
Aer. aerogenes—131	245	46,500	46,200,000	1,100,000,000
Esch. coli—167	182	37,500	103,000,000	1,530,000,000

* The medium consists of: Bacto-tryptose 3 per cent, lactose 0.5 per cent, K_2HPO_4 0.4 per cent, KH_2PO_4 0.15 per cent, NaCl 0.5 per cent; medium adjusted so pH 6.7 after sterilization was obtained.

These results do not in any way fail to confirm the work of Hershey and Bronfenbrenner (5) since their observations were made at the end of two days incubation and the above-mentioned observations were limited to 8 hours incubation.

For comparative purposes and uniformity of data, only one strain of the coliform group was used, namely *Esch. coli*, No. 161. To check the effectiveness of the tryptose lactose medium in growing the coliform organisms from their stationary phases, five strains of *Escherichia coli* and two strains of *Aerobacter aerogenes* were tested. The results are presented in table 11. No cases of marked retardation were observed although there was a difference in the rates of reproduction during the early growth phases.

Comparison of Lactose Peptone and Tryptose Lactose Broths

Throughout all of the studies presented in this paper, comparisons of the tryptose lactose medium were made with standard lactose peptone broth. In table 12 three comparisons are presented. In these comparative tests, as well as in all of the other tests, wherein these two media were compared, the tryptose lactose medium was far superior to standard lactose peptone broth at all stages of growth. In all instances, the periods of stationary and lag phases were much

TABLE 12

Comparison of Standard Lactose Broth and Lactose Tryptose Buffer Broth for Rate of Growth of Esch. coli, No. 161

MEDIUM	pH	SERIES NO. 1				
		Number of bacteria per ml.				
		Initial	3 hours	6 hours	9 hours	12 hours
Standard*	6.55	51	960	79,000	7,750,000	229,500,000
Tryptose†	6.8	64	5,885	1,440,000	970,000,000	2,205,000,000
		SERIES NO. 2				
Standard	6.8	29	49	2,300	62,000	360,000,000
Tryptose	6.8	49	420	80,300	115,000,000	2,070,000,000
		SERIES NO. 3				
		Initial	2 hours	4 hours	6 hours	8 hours
Standard	6.8	25	41	455	25,000	1,235,000
Tryptose	6.8	27	72	1,785	170,000	13,600,000

* Standard: Bacto-lactose broth, A.P.H.A.

† Tryptose, medium consists of: Bacto-tryptose 2 per cent, lactose 0.5 per cent, K_2HPO_4 0.4 per cent, KH_2PO_4 0.15 per cent, NaCl 0.5 per cent.

shorter in the tryptose lactose broth, indicating very clearly that this medium allowed the rapid development of the viable cells by the fact that it offers a much better environment for the early reproduction of the organisms. This, in turn, means that more viable cells will reproduce so that the colon index will be higher in this medium than in standard lactose peptone broth particularly if the coliform organisms present have been attenuated.

The physiological by-products of metabolism parallel roughly the rate of reproduction of the organisms. In tables 13 and 14 data

are presented to show the time of appearance of gas. Three media are presented, the proposed tryptose lactose broth, the same medium minus buffer, and standard lactose peptone broth. An examination of the data shows that gas appeared sooner in the tryptose media than in the standard lactose peptone broth and that the quantity

TABLE 13

Influence of the Medium on the Rate of Gas Production of Esch. Coli, No. 161 (Series No. 1)

MEDIUM	TUBE NUMBER	TIME OF APPEARANCE OF GAS AND GROWTH									
		9.5 hours		10.5 hours		11.5 hours		12.5 hours		13.5 hours	
		Visible growth	Gas	Visible growth	Gas	Visible growth	Gas	Visible growth	Gas	Visible growth	Gas
1	1	+	+	+	10	+	40	+	60	+	90
	2	+	+	+	15	+	40	+	60	+	80
	3	+	+	+	10	+	40	+	60	+	80
	4	+	+	+	15	+	40	+	70	+	80
	5	+	+	+	20	+	50	+	70	+	90
2	1	+	+	+	2	+	20	+	40	+	60
	2	+	+	+	20	+	60	+	70	+	70
	3	+	+	+	40	+	75	+	80	+	90
	4	+	+	+	25	+	60	+	70	+	80
	5	+	10	+	50	+	75	+	80	+	90
3	1	±	−	+	−	+	−	+	5	+	20
	2	±	−	+	−	+	+	+	5	+	10
	3	±	−	+	−	+	−	+	10	+	15
	4	±	−	+	−	+	−	+	5	+	10
	5	±	−	+	−	+	+	+	10	+	20

Medium 1 consists of: Bacto-Tryptose 2 per cent, lactose 0.5 per cent, NaCl 0.5 per cent, K_2HPO_4 0.4 per cent, KH_2PO_4 0.15 per cent.

Medium 2 consists of: Bacto-Tryptose 2 per cent, lactose 0.5 per cent, NaCl 0.5 per cent.

Medium 3: Bacto-lactose-peptone broth.

Inoculum: 580 organismo per tube.

of gas was far greater in the former media. The non-buffered tryptose broth showed more gas than the buffered medium at the same early periods due to the fact that the fall in pH was more rapid in the non-buffered medium; hence there would be less conversion of the carbon dioxide to carbonates. As would be expected from an

examination of the growth curves of the various media, visible turbidity appeared earlier in the tryptose media.

The value of growth rates, particularly during the lag and early logarithmic phases for the evaluation of a nutrient medium rather than maximum growths is clearly demonstrated. For example, in

TABLE 14

Influence of the Medium on the Rate of Gas Production of Esch. Coli, No. 161 (Series No. 2)

MEDIUM	TUBE NUMBER	TIME OF APPEARANCE OF GAS AND GROWTH									
		11 hours		13 hours		14 hours		15 hours		24 hours	
		Visible growth	Gas	Visible growth	Gas	Visible growth	Gas	Visible growth	Gas	Visible growth	Gas
1*	1	+	−	+	−	+	−	+	10	+	90
	2	+	−	+	−	+	−	+	10	+	90
	3	+	−	+	−	+	−	+	+	+	100
	4	+	−	+	−	+	5%	+	5	+	90
	5	+	−	+	−	+	5%	+	5	+	90
2	1	+	−	+	−	+	5	+	20	+	70
	2	+	−	+	−	+	+†	+	5	+	70
	3	+	−	+	−	+	10	+	5	+	60
	4	+	−	+	−	+	+	+	10	+	60
	5	+	−	+	−	+	+	+	20	+	70
3	1	−	−	±	−	±	−	+	−	+	10
	2	−	−	±	−	±	−	+	−	+	20
	3	−	−	±	−	±	−	+	−	+	20
	4	−	−	±	−	±	−	+	−	+	10
	5	−	−	±	−	±	−	+	−	+	10

* Medium 1 consists of: Bacto-tryptose 2.0 per cent, lactose 0.5 per cent, NaCl 0.5 per cent, K_2HPO_4 0.4 per cent, KH_2PO_4 0.15 per cent.

Medium 2 consists of: Bacto-tryptose 2.0 per cent, lactose 0.5 per cent, NaCl 0.5 per cent.

Medium 3: Bacto-lactose-peptone broth.

† Bubble of gas is indicated by +.

Inoculum per tube: 40 organisms.

table 6, in measuring the significance of pH in the growth of *Esch. coli*, the medium of pH 6.8 gave a count of 31,800 in 6 hours incubation while the medium at pH 7.8 gave a count of 7,900. At the end of 48 hours incubation the medium at pH 7.8 showed a count of 2,630-000,000; whereas the medium at pH 6.8 showed only 880,000,000

organisms. If the two media were measured by total growth, the medium at pH 7.8 is superior but if the media were measured by the initial number of viable cells that reproduce, the medium at pH 6.8 is far superior. It is quite evident that the medium at pH 7.8 does not offer a favorable environment for the development of the viable cells present and hence such a medium would be an unsatisfactory diagnostic or enrichment medium.

Another example of the value of this procedure is shown in table 8 in the influence of sodium chloride in the medium on growth rates. The amount of growth in both the salt and non-salt media is approximately the same at the end of 48 hours incubation whereas at the end of 6 hours incubation the salt media show a much higher count. If the media were measured at the end of 48 hours incubation, it would appear that salt had no appreciable value in the medium; whereas at the end of 6 and 12 hours incubation, it is quite evident that salt increases growth rates materially. Repeatedly during this study similar experiences have occurred, demonstrating the value of the growth rate method for the development of a culture medium designed for diagnostic purposes.

It is realized that the medium presented in this paper differs radically from the present standard lactose peptone medium, but it is the opinion of the writers that an enrichment medium used as a presumptive medium for the detection of the coliform organism should allow the development of all viable cells present in the material to be examined. This medium based on studies made with minimal numbers of viable cells shows that a much greater rate of reproduction occurs during the lag and early logarithmic phases of growth with a materially shorter stationary phase than standard lactose peptone broth would show. That it does allow the development of more viable cells than standard lactose peptone broth was demonstrated this past summer on swimming pool samples.

The use of this medium on routine water analysis has not as yet been tested on a wide scale. At the present writing it is being used in seven water purification plant laboratories in parallel with standard lactose peptone broth for comparative purposes. The results of this study will be presented at a later date.

The medium is being presented at this time to give water analysts an opportunity to make comparative tests so that it will be possible to determine whether or not its use would be worthwhile for routine use in place of the standard lactose peptone broth.

Summary

1. Bacto-tryptose was found to be superior to Bacto-peptone in a base medium for all growth phases of *Esch. coli.*

2. A concentration of 2 per cent Bacto-tryptose in the medium was found to give the greatest rate of reproduction during the lag and early logarithmic growth phases.

3. The addition of phosphate buffer to the medium caused a much greater growth in the late logarithmic phase and a slightly greater increase during the lag phase than the non-buffered medium.

4. The rate of growth during the lag phase was greatest at a pH of 6.8.

5. The concentration of lactose appeared to have no influence on the rate of growth during the lag and early logarithmic phases.

6. The addition of 0.5 per cent sodium chloride to the medium caused a marked increase in the rate of reproduction during the lag and early growth phases.

7. A 2 per cent Bacto-tryptose lactose buffered broth was far superior to standard lactose peptone broth for the growth of coliform organisms during the lag and early logarithmic phases. The increase in numbers persisted into the late logarithmic and decreasing logarithmic phases of growth.

8. The medium is suggested as an enrichment medium for the growth of coliform organisms. The formula follows:

Bacto-tryptose	2 per cent
Lactose	0.5 per cent
K_2HPO_4	0.4 per cent
KH_2PO_4	0.15 per cent
NaCl	0.5 per cent

pH before sterilization: 6.8

In a subsequent paper the results showing the use of this medium as a presumptive medium for the detection of the coliform organisms in water supplies will be presented.

EDITOR'S NOTE. This paper has been published at the request of the Executive Committee of the Water Purification Division in the hope that the media therein suggested will be extensively tested elsewhere so that experiences may be summarized in a discussion before the Water Purification Division.

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Simplified Bacteriological Examination of Water

By James E. Weiss and Charles A. Hunter

FOR many years investigators have been interested in a more simplified method of determining the potability of water, one which would eliminate the false presumptive tests, while still retaining the efficiency of the standard lactose test. Many procedures have been developed but few, if any, have proven as efficient as the standard. This does not mean, however, that the standard method is ideal; it is very time consuming, shows many false positives, and at best is far from 100 per cent efficient. A method, therefore, which is rapid, shows few false positives and is decidedly more efficient would be welcome.

Nearly all procedures which have attempted to improve the method of water analysis have used the same basic principle, that of using broth, which will, if coliform organisms are present, show acid and gas formation. Thus, Theobald Smith (12), in 1893, used glucose broth as a presumptive medium, but this was changed to lactose (1917) and, with slight changes, lactose broth remains the present day standard (1936).

Most investigators nowadays utilize various dyes in a lactose broth base, in order to hold in check spurious or false presumptives. Hall and Ellefson (3) in 1918 used gentian violet; Muer and Harris (6) in 1920, brilliant green; Dunham, McCrady and Jordan (2) in 1925, and Jordan (4) in 1927, brilliant green and oxgall; Salle (10, 11) in 1929 and 1930 and Stark and England (14) in 1933, crystal violet; Dominick and Lauter (1) in 1929, Salle (11) in 1930, and Leahy (5) in 1930, brom cresol purple; Ritter (7) in 1932, basic fuchsin, and

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Stark and England (15) in 1935, formate ricinoleate broth; all of whom have pointed out the advantages of their media over the standard lactose broth.

In 1935 Ruchhoft and Norton published a report on a study of selective media used for the presumptive test. It was shown that all the trial media were less productive of coliform organisms than the standard lactose broth. Ruchhoft (8) in 1935 concluded that the standard method detected the presence of the coliform group in only about 77 per cent of all lactose presumptives and noted "that the standard procedure is far from a perfect method."

It is the authors' opinion that so long as the acid and gas type of reaction is made the basis of water examination there will be little chance of obtaining a method superior to the standard presumptive test. If one should, however, attack the problem from another angle, a more efficient method might be devised.

Larger Quantities of Water Used

In recent years another trend has been evident in bacteriological analysis, that of using larger quantities of water in the examination. The theory behind this seems reasonable because potable water should be free of coliform organisms either in large or small quantities. It is true that the application of the dilution method for the presumptive test will indicate the relative number of organisms present but according to present standards the number of coliform organisms has little significance. Certain it is that the authors' experience has been that small quantities have sometimes been negative or at best suspicious, whereas larger quantities have proven to be contaminated. One would naturally pick up traces of contamination by using larger quantities, but such traces are just as indicative of the possibility of fecal contamination as is heavily contaminated water.

The method to be proposed here is one which utilizes several of the aforementioned procedures. It is rapid, efficient and simple. It shows far less false positives and many more confirmed positives than does the standard. It utilizes larger quantities of water, with the amount to be used varied to suit individual conditions. The method is adaptable either for plant operators or for water sent into the laboratory from the field.

In all, 638 samples of water sent into the laboratory for routine examination were studied. Each sample was examined according

to the standard method and also by the special or "bottle" method. The water samples came from various sources throughout the state: shallow and deep wells, artesian wells, streams, rivers, and lakes. The samples were divided between raw private and town supplies, and treated, chlorinated city supplies. Most of them were collected by district health officers or trained field men. The number and types of samples, also the per cent of samples showing contamination, are quite representative of the water supply of South Dakota.

The standard method as used in this laboratory utilized 51.1 c.c. of water. For the presumptive test, seven tubes of lactose broth were inoculated, one tube receiving 0.1 c.c. of water, another 1.0 c.c., and each of the remaining 5 tubes was inoculated with 10 c.c. of water. The lactose broth was prepared, either from Difco dehydrated or from raw ingredients according to *Standard Methods* (1936). It was put up in large tubes, approximately 20 c.c. per tube. Readings were made at 24 and 48 hours, positive tubes were further examined by streaking on eosin-methylene blue agar, typical colonies confirmed in lactose broth and bacto-brilliant green lactose bile 2 per cent.

Broth Added to 150 c.c. of Water

The bottles, as they came into the laboratory, contained approximately 200 c.c. of water; of this amount 51.1 c.c. were used in the standard test, leaving approximately 150 c.c. in the bottle. It occurred to the authors to use this relatively large amount of water. The method finally selected was the addition to this water of a certain amount of concentrated nutrient broth, so that the final concentration in the bottle consisted of ordinary extract broth (0.3 per cent beef extract, 0.5 per cent peptone). In this investigation Difco dehydrated broth was chiefly used. The concentrated broth was made in 100 c.c. quantities, 24 grams of dehydrated broth per 100 c.c. of water. In the test, 5 c.c. of this concentrate were added to each bottle which contained approximately 150 c.c. of water, with the result that the bottle consisted of about 155 c.c. of nutrient broth. Later in the investigation the concentrated broth was made directly from beef extract and peptone and proved both easy to prepare and as satisfactory as the dehydrated product. The amount of broth to be used and its concentration are, of course, a variable depending entirely on the amount of water under examination.

No carbohydrate is added to the broth, first, because gas formation is not measured and, second, because gas would be troublesome in glass stoppered bottles.

After adding the concentrated broth to the water in the bottle it was incubated at 37°C. over night. The following day a loopful of the broth from the bottle was streaked on eosin methylene blue agar and the plate was incubated until the next day, when colonies were fished off into lactose broth and Bacto-brilliant green bile 2 per cent for confirmation.

The relative advantages and disadvantages of the standard and the bottle methods will be taken up under another section. At this point the authors would like to present the results obtained from the study of these two methods on 638 waters sent to this laboratory for routine examination from January to June, 1937.

Total number of water samples	638
Number positive by both methods	189 or 29.6 per cent
Number negative by both methods	384 or 60.2 per cent
Number in which there was disagreement	65 or 10.2 per cent
Standard + Bottle −	12 or 1.9 per cent
Standard − Bottle +	53 or 8.3 per cent
The difference in favor of bottle method	41 or 6.4 per cent

Thus it is seen that, in a fairly representative number of waters, the bottle method picked up 8.3 per cent more waters showing the coliform organisms than did the standard. It is, of course, also true that the standard method picked up 12 or 1.9 per cent waters showing the coliform organisms where the bottle method failed to do so. If one, however, considers the total number of positives, that is the sum of the positives by each method, the bottle method will prove to be more efficient by 6.4 per cent. The authors, because of this investigation, have been convinced that the bottle method is more reliable and gives a truer picture of the potability of the water.

An objection might be raised that the bottle method is too sensitive, but analysis of the figures obtained in this study will soon refute such a belief. Sixty per cent of all the waters studied were negative for the coliform organisms demonstrating that a water free of these organisms can be and is possible. The number of waters positive by the bottle method, but negative by the standard procedure is great enough to be significant, and yet not so great that it would show the test as too strict or too sensitive. Furthermore, the bottle method, in several instances, gave positive results, the standard

negative, in which cases a sanitary survey of the water supply showed possible danger.

So long as fecal contamination is possible, water-borne diseases are possible, and therefore slight contamination is as potential a source of danger as is heavy contamination.

Time and Materials Saved

The increased efficiency of the bottle method is not, however, the only factor for its recommendation. This method saves both time and materials. It does away entirely with the lactose broth fermentation tubes used in the presumptive test. The simple procedure of adding a small quantity of concentrated broth to a bottle of water and placing it in the incubator, is a time saving device which is appreciated in a busy laboratory, where many waters are examined. By streaking from the bottles, after incubating at 37°C. for 15 to 18 hours, a day's time is saved, since the standard method usually requires 48 hours.

Whether it is a peculiarity of South Dakota or not, the authors are not certain, but at least 75 per cent of the waters coming to this laboratory show acid and gas in lactose broth in 48 hours. This gas formation is usually due either to lactose fermenting spore formers or synergism.

When such gas appears it is necessary to streak from these tubes, pick colonies and attempt to confirm the results. A large percentage of these reactions do not confirm, but in the meantime the final report on these waters is delayed for several days.

Surprising as it may seem, no such difficulty is encountered with the bottle method. If coliform organisms are present, they appear in large numbers and are easily confirmed. If coliform organisms are absent, but spore formers or synergists are present, they either fail to grow in the bottle or the growth is easily separated on the eosin methylene blue agar plate. Thus it was, that during this investigation negative samples were, in many cases, finished by the bottle method several days in advance of the standard procedure. It was thought, at one time, of adding brilliant green-bile to the broth in the bottle, thus holding down the spore formers, but such a procedure did not prove to be necessary.

An objection to the bottle method might be raised in that it does not show the extent or degree of contamination. This is true, for after incubation a positive water contains larger numbers of coliform

organisms whether originally it was lightly or heavily contaminated. The question arises, however, as to how much a quantitative knowledge means, since by the standard method, if one tube is positive in one water, whereas all tubes are positive in another water, both waters are considered unsafe, and rightly so. The method of determining potable water by laboratory examination today rests wholly on the presence or absence of coliform organisms, and that being so, the bottle method will be more efficient in discovering these organisms.

Field Samples Are Grown in Transit

A logical development of the bottle method would be the sending out of sterile bottles containing the required amount of concentrated broth. This was tried during the closing week of the investigation. Duplicate bottles were sent to the field men, one bottle containing 7 c.c. of concentrated broth, the other empty. Samples were then taken and shipped back to the laboratory by parcel post. The plain bottle was run by the standard method, the other containing the broth and having been in transit from one to three days before being delivered to the laboratory had already developed growth. All that was necessary was to streak eosin methylene blue agar plates from the bottle and incubate overnight at 37°C. In many cases the colonies were so typical that a final report might be made, if necessary, in 24 hours.

The number of samples examined by this method was too small to be significant, but the method showed definite promise, for in 30 samples of water it did not miss once, when compared to the standard method. It did, however, pick up coliform organisms in 3 samples which the standard method missed.

This extremely rapid method was found very convenient in testing waters from tourist camps, scout camps and summer resorts, since it is often necessary to know the potability of such waters as soon as possible.

The use of this bottle method for checking the efficiency of water treatment plants is especially recommended. A good many of these small plants have neither trained operators nor sufficient laboratory equipment to test the water by the standard method, but the bottle method is so simple that operators can be taught to carry out the procedures, with satisfactory results.

Conclusions

A rapid and efficient method for the determination of potable water is described. The method is based on the addition of a certain amount of concentrated broth to the water sample, thus making simple nutrient broth of the water under examination. After 24 hours a loopful of the broth is streaked on eosin methylene blue agar and confirmed in the usual manner.

By this method 8.3 per cent more waters were found to contain coliform organisms than by the standard lactose broth method. The "bottle" method also proved to be much more rapid, showed fewer false reactions, and in addition to being more efficient, was simpler and cheaper to operate.

A method is also mentioned of sending bottles containing the required amount of concentrated broth into the field so that by the time the water reaches the laboratory, growth has occurred and confirmation can proceed. With such a method it is possible at times to give a definite report in 24 hours, but under any circumstances it will not take longer than 48 hours to complete the examination.

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Sanitation of Recreational Areas

By Frank M. Stead

FEW areas in California are as full of interest for the historian, geologist, or lover of the outdoors as the mountain range which extends across the central portion of Los Angeles County. Recently formed by the vertical uplift of a huge block of once gently sloping plain, it is still undergoing the rapid change of appearance that we associate with the period of infancy. Its steep boulder-strewn canyons terminating in broad alluvial cones, and its barren rocky slopes all bespeak a mountain range not only of striking beauty but one of sudden terrible floods and tremendous erosion possibilities.

This area was too large and inaccessible to be carried along with the wave of development which swept over the valley area to the south where early mission life has long since given way to the bustle of cities. In the mountain area may be found the unchanged homes of settlers of the time before the Gold Rush, occupied by people who still practice and preserve the charm of life of an earlier day.

When an area such as this is situated immediately adjacent to a huge metropolitan district made up largely of pleasure-loving outdoor people, it is only natural that it should be widely used for recreational purposes, especially when good roads make all parts of it easily reachable in a short time. The picture presented by the mountain area today, therefore, is one of contrast. The early bona fide settlers of the mountain region are still there but have been so far outnumbered as to be almost obscured by the thousands of people who weekly use the mountains as a playground. Some of these people occupy the 6,000 private cabins in this area, others patronize the many commercial resorts and children's summer camps, but the largest proportion of this huge crowd of pleasure seekers, numbering several

A paper presented at the California Section meeting at Riverside, California, October 27, 1938, by Frank M. Stead, Assistant Epidemiologist, Los Angeles County Health Dept., Los Angeles, Calif.

million a year, flock to the county playgrounds at Big Pines and Crystal Lake or use the 250 public picnicking areas along the running canyon streams, although many of these latter are now closed as a result of the recent flood.

To make possible this wide usage of the mountain area, over 40 labor camps using from 50 to 300 men each have tackled the huge job of building roads, dams, safe water supplies, fire prevention work and camping facilities. Men in these camps are prisoners, youths on probation, S.R.A. men, C.C.C. boys, members of the forestry department or flood control district or employees of private contractors, and the agencies represented range from private individuals to departments of county, state and federal government.

Health Department Is Responsible

It may truthfully be said that virtually the only problems which all of the diverse types of people in the mountain region have in common are those of sanitation. It therefore falls upon the health department to be in a sense the one coördinating factor of all these various lines of activity, and to develop a program practical and constructive enough to be carried out willingly by all these diverse agencies. Such a program must be simple and constructive and at the same time scientifically sound. It must deal only with things vitally important and not occupy itself with valuable but trivial lines of activity. Incidentally, it must frankly face facts and dodge no embarrassing issues.

We believe that we have such a program in the Division of Mountain Sanitation of the Los Angeles County Health Department and it is the purpose of this paper to outline its broad features.

The two problems of sanitation that appear to be most important in the mountain area are those of water supply and sewage disposal. These two fields are of prime importance in any area but in the mountains they are especially so.

The mountains may be conceived of as being composed of a relatively impervious foundation overlaid with a thin blanket of porous material made up of sand, rock, and soil. The water supply for the area coming in the form of rain and snow is deposited on the surface of this porous blanket and immediately starts to flow downward toward the foot of the mountains, tending to concentrate itself in the canyons where incidentally the population is also concentrated. Some of this water flows rapidly on the surface, but a large part of it flows underground at rates from five to fifty feet per day.

After floods such as the recent one, there is the special case of water flowing underground in the boulder-filled flood canyons at velocities substantially the same as those of the surface streams. Water supply and sewage disposal problems are made critical by the fact that it is necessary to develop drinking water and dispose of sewage in the same thin porous top layer or blanket and to do both of these things alternately many times in the same canyon.

Layman Is Designer and Engineer

As if this were not trouble enough, conditions in the mountain area are such that these two types of work cannot be assigned to men with training and experience along these lines but usually fall to the lot of each individual resident. Thus John Smith, who is, let us say, a store clerk, has all his life drawn water from his kitchen tap and used his flush toilet without giving any conscious attention to what is behind each of these two common household appurtenances. When he builds a mountain cabin, he suddenly finds himself obliged to become for a time a water supply and sewage disposal engineer and to so design and build his own facilities that his drinking water will not reflect the mistakes of neighbors' sewage disposal methods and so that he will not cause people lower down to drink sewage-contaminated water from their springs or wells or from the stream itself. He is dealing with a complex and involved subject and yet it must be explained understandably to him if he is to coöperate willingly and intelligently. The same principles apply to work in the many camps and resorts in the mountain area to an even greater degree.

A solution of the above described problems requires a knowledge of the behavior of sewage organisms in an environment such as that found in the porous blanket of the mountain area. The best knowledge now available, gleaned from the literature and from experimental work in various localities, may be stated in part in the following laws or theorems:

1. Sewage organisms discharged with water into the ground do not spread in all directions but percolate straight downward in a beam until they reach the water table or strike an impervious surface.

2. In making such a downward trip toward the water table, sewage organisms will cause the growth of a gelatinous coating on the grains of soil structure through which they pass and this gelatinous coating will then be capable of

removing sewage organisms and solids from the downward percolating water.

3. Once reaching the water table, the sewage organisms will travel freely with the water both in direction and velocity but will largely remain at the surface of the water table.

4. Sewage organisms traveling at the surface of the water table will not be filtered out or absorbed by the material through which they pass, but, being in an unfavorable environment, will not vegetate but live out their life period and die.

Translating these four statements into terms of actual field practice, in sewage disposal we attempt to provide one or both of the following conditions:

1. A downward percolation of sewage through at least a 10-foot depth of fine unsaturated material above the water table.

2. A horizontal travel with the water table of at least 30 days before reaching any source of water supply.

In the field of water supply our aim is to develop water from a source which has either undergone a sufficient period of underground travel to remove all hazard or to take water from a point 15 or 20 feet below the surface of the water table.

Considerable Field Work Necessary

These few basic considerations, simple as they are, involve a surprising amount of field work in their application. Various types of augers and driving-rods are needed to explore the soil formation between the ground surface and the water table. The measuring of the length of time of horizontal travel of the water table from any point to the nearest source of water supply requires the measurement of both direction and velocity of ground water. We have made use of extremely sensitive electric recording equipment developed by one of our own staff, for the purpose of tracing the travel of a salt solution introduced into a test hole to determine ground water direction and velocity.

Comparative tests made both with the use of the electrical method and with fluorescein dye have indicated that the latter method cannot be relied upon to give a true measure of ground water velocity. In some cases we have found fluorescein to travel at less than half the velocity of the water in which it was suspended. It is suggested that some of the earlier published tests in which this dye was used to record

velocity in measuring the viability of coliform and typhoid organisms, the computed time of travel from test hole to farthest point of recovery of organisms may have led to an erroneous opinion of the life period of these organisms in ground water.

Several Methods Used for Sewage Disposal

When large amounts of sewage are to be disposed of underground, a new consideration comes into the picture: how extensive a disposal works is needed to put the sewage into the ground successfully and keep it there? Generally speaking, in the mountains sewage is usually first clarified by means of a septic tank and the effluent is put into the ground by means of some leaching device. Leaching devices vary from shallow trenches employing loose-jointed tile laid on crushed rock on the one extreme to deep cribbed cesspools on the other. In between these two extremes are many special types partaking of the features of both. Most commonly used of these is the long shallow cesspool usually in units 30 to 50 feet long, 3 to 5 feet wide and 4 to 6 feet deep. These may be cribbed with wood, filled with crushed rock, or provided with a center box surrounded by a 12-inch jacket of crushed rock on sides and bottom. In any event, a top covering layer of earth is used.

A clear understanding of the advantages and limits of each type of leaching unit is needed if proper design is to result. The shallow leaching trench provides greatest clearance above the water table and the largest area of soil exposure for leaching but requires the most space for its installation. The deep cesspool requires the least space but penetrates closer to the water table and is not suitable where only a relatively thin layer of porous material overlies impervious rock or water table.

The foregoing principles and considerations appear a bit confusing on first glance but when applied logically and in the proper order they are extremely valuable and workable and furnish an excellent working basis for designing sewage disposal systems. Let us take an actual case and follow the procedure through from start to finish. Let us say that John Doe has a mountain cabin near the stream in one of the canyons and wishes to install a sewage disposal system for all his waste water including that from a flush toilet.

The first step is to size up the general layout from a water point of view noting the location of all streams, wells, springs, and standing bodies of water in the vicinity. Next, enough observation is made to

indicate the probable underground water picture as to depth of water table and direction and velocity of underground flow. This step frequently requires the use of special tools actually to dig to water level and note the type of soil. Step three is the selection of the most favorable spot for disposal that can be reached by gravity from the cabin in question and the tentative selection of the type of leaching unit best suited to the area.

The next step is the most important. Decision must now be made on two points. First, will liquid from the bottom of the leaching unit have an opportunity to travel vertically downward through sand or soil, a distance of 10 feet before striking ground water or impervious rock? Second, after striking ground water will the direction of flow and distance and velocity of travel of said ground water be such as to require 30 days before reaching any well, spring or surface stream. This step also requires actual tests of ground texture and water level, and in some cases measurement of ground water velocity. Usually, however, it is assumed that if the material is reasonably fine sand or soil, the ground water velocity for normal gradients will not exceed 10 feet per day. This figure decidedly does not apply to open gravel. If the answer to both the above described considerations is favorable, it only remains to be ascertained if the ground can absorb the required amount of liquid.

Tests Determine Leaching Ability of Soil

The means employed to acquire this information is actually to test the leaching ability of the soil by means of test holes. The test hole is dug with a 4-inch auger where possible to the depth of the proposed leaching unit and filled with water to the proposed maximum water level. Measurement is then made of the time required for this measured initial amount of water to disappear. The experiment is repeated until two successive test times substantially agree. Usually this requires at least three runs.

Next a unit rate in gallons of water leached per square foot of wetted area per day is computed and the size of the leaching unit is designed on the basis of this rate and the expected amount of sewage with a liberal factor of safety. In actual practice we have developed certain minimum sizes for leaching units which are required even though the tests indicate that a smaller unit would work satisfactorily.

The question will already have occurred to the reader—what if

the above described requirements cannot be met? The answer is that the applicant must make use of some other form of sewage disposal than a water-flushed toilet. The reason that a water-flushed toilet is considered to be more hazardous than other forms is that it involves 80 times as much water to be disposed of as either a pit privy or chemical toilet. Consequently, more leniency can be permitted in the installation of these latter forms of toilet. What our actual requirements are for these two types will not be discussed in this paper but minimum standards based on the considerations previously discussed have been established.

Chemical or Water-tight Toilets Are Last Resort

In locations where even these modified standards cannot be met, the owner is limited to a choice between a blind chemical toilet which has no outlet but is pumped out when full or a deep concrete vault privy of water-tight construction. The latter type properly vented, and so constructed as to permit regular burning out, has been used in mountain cabins with excellent results for years at a time without filling with either liquid or solids. In installations receiving heavy use, it is desirable to so construct the vault that solids will be retained in a compartment suitable for burning out while the liquid is collected in a sump where it can be pumped out. Distillate is used for burning out and the secret of success is regular burning at frequent intervals. Burning is accomplished without removing the building. The principal object sought is the shrinking of bulk by burning of the paper and evaporation of moisture.

The problem of water supply is of course the justification of all work on sewage disposal in a recreational area and must always receive first consideration. By giving attention to the principles of travel of sewage contamination previously discussed, it is usually possible to develop safe water from underground sources even in areas downstream from sewage disposal facilities. As mentioned, the primary considerations are depth below the water table and period of elapsed time since the last previous contamination. Another equally important consideration is the protection of the supply from the entrance of water or seepage from some outside source. Hence, proper sealing of wells and springs at the surface, impervious side walls on wells, and properly constructed manholes and covers are all important items.

From a recreational standpoint, however, perhaps the most im-

portant water supply consideration is the widespread practice of drinking stream water. Popular ideas on this subject are so strongly believed that they constitute almost a superstition. The subject cannot be raised in any group without someone asking, "But doesn't running water always purify itself when running over rocks?" The writer can personally testify to the looks of pity for his ignorance which he has on occasion called forth by implying that the cold sparkling water in some rippling mountain stream might not be as pure as it looked.

Drinking Water Hazard Is Tenuous

This question of the hazard involved in drinking stream water is not an easy one to prove or demonstrate. In the first place sewage contamination when it does occur is probably not continuous for any period of time but extremely intermittent so that two persons might drink in turn from the same stream and one drink safe water and the other dangerously infected water. A study of the matter by means of bacteriological analysis is complicated by the fact that the coliform test reflects the presence of sewage from animal as well as human sources while only human sewage can render the water dangerous.

A third obstacle is the fact that there is no tolerance for coliform even of human origin that can be said to represent the safe limit of human sewage contamination even assuming the sewage to be infected with disease organisms. The Treasury Department standards cannot properly be construed as the maximum safe limits of bacterial contamination in water. The literature contains no records of any limit of bacterial contamination above which outbreaks of disease occur and below which they do not. Many of the recent outbreaks of typhoid fever in this state have been caused by water so grossly contaminated that it was almost sewage itself.

These obstacles, imposing as they may seem, however, are no excuse for shirking the question.

Since January, 1936 we have carried on an intensive study of the bacteriological quality of mountain stream water. Fifty of the major streams are included in the study which has involved an attempted sampling frequency of once every month from each station. The factor of variability we have attempted to iron out by the large number of samples from each point (over 2,000 samples have been analysed). Distinction between animal and human sewage has been attempted by careful selection of sampling points. Each stream has

two sampling stations, one at the upper region above any human habitation and one near the canyon mouth. Taking all streams together, the average of coliform content of all upper station samples gives an index of animal contamination while a similar figure for lower stations gives an index of animal plus human contamination. The amount by which the second figure exceeds the first is considered to be the index of human contamination.

Tests Show Increase in Human Sewage

The period during which this study has been carried on is of especial interest because it begins with two years of normal rainfall and ends with a year of abnormally large and intense rainfall with resultant heavy run-off and stream flow. Translating the results obtained from the three years of tests at upper and lower sampling stations into terms of human versus animal sewage contamination, we have the data shown in table 1. These results indicate that for the past

TABLE 1

Increase of Human Sewage in Streams

	1936 COLIFORM PER C.C.	1937 COLIFORM PER C.C.	1938 JAN.-SEPT. COLIFORM PER C.C.
Human	0.25	0.88	1.19
Animal	1.19	0.76	0.78

three years there has been a steady increase in the degree of human sewage load carried by the running streams of Los Angeles County and that this increase has continued even in the face of the large amount of run-off available for dilution during the present year. It should be borne in mind that these figures refer to the mountain area as a whole and not merely to the canyons most damaged by the recent flood of March, 1938.

To sum up, it may be said that problems of water supply and sewage disposal in mountain and recreational areas are not always easy of solution but they lend themselves to scientific analysis just as really as do the problems of municipal water and sewage treatment. A program of sanitation flexible enough to permit each problem to be studied and solved on its own merits is far more satisfactory to all involved than an arbitrary attempt to apply the same remedy to every situation. This flexibility, however, must be based on an adherence to scientific principles and not reflect merely the snap judgment of the inspector.

An extended study of the bacteriological quality of water in the running streams of Los Angeles County has indicated that the trend of human sewage contamination is upward in spite of continued effort to improve methods of sewage disposal in the area. It seems reasonable to suggest, therefore, that water from safe sources should rapidly be provided to replace the use of raw stream water for drinking purposes.

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Recreational Use of Reservoirs

By Earl Devendorf

THE problem presented in connection with any program of permitting boating, fishing, and other recreational activities on large reservoirs, lakes, and their tributaries has been the subject of discussion among water works men at their meetings for a number of years. References are given below in an attempt to make available some of the more recent, important articles and discussion on this subject.

The eastern states, more particularly New England, have generally advocated very restrictive regulations governing the protection of watersheds tributary to public water supplies. In part this may be the result of conditions set up in colonial grants where ponds over ten acres in area were designed as "great ponds" and were the property of the Commonwealth. In some of the western states the recreational use of watershed lands has been widely advertised in recent years. In other states, where the supplies are obtained almost exclusively from wells or large rivers or bodies of water, the state health departments have never attempted any control or regulation of sanitary conditions on watersheds, except insofar as the treatment of the sewage of municipalities is concerned.

In New York State, through the provisions of the Public Health Law, the State Commissioner of Health is empowered to enact rules and regulations for the protection from contamination of public water supplies. Many such rules and regulations have been enacted which restrict the location of permanent sources of pollution, such as privies, cesspools, etc., and also restrict temporary acts of pollution such as boating, bathing, and fishing in reservoirs and lakes used as

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A paper delivered at the New York Section meeting, Poughkeepsie, New York, September 23, 1938, by Earl Devendorf, Associate Director, Division of Sanitation, New York State Department of Health, Albany, N. Y.

sources of water supply. Such temporary acts are usually prohibited within limited distances of the water supply intake.

In an opinion of the State Attorney-General's office rendered many years ago, it is stated that the enforcement of any provisions of the rules and regulations enacted by the State Commissioner of Health could not be made effective by water supply authorities if they involved the deprivation of riparian owners of their private property rights unless and until payment had been made for such loss of rights. To be effective any rules and regulations enacted by the State Commissioner of Health must be capable of enforcement without excessive and prohibitive cost to the municipality and still prevent dangerous pollution of the supply by the direct discharge of sewage and household wastes.

State and Local Officers Enforce Regulations

The advent of the automobile and the resulting increase in the number of organized camps and summer cottages on the larger watersheds and lakes have complicated the protection of water supplies. Chapters VI and VII of the (New York) State Sanitary Code pertaining to swimming pools and summer camps contain regulations to the effect that pools and camps must be so operated as to protect public water supplies, and that enforcement of the Code is to be by local health officers and the State Department of Health to the end that these recreational facilities are not a menace to the public health.

The situation in regard to summer cottages is more complicated, especially with those located near the shore line of lakes. Experience has shown that best results are secured by the enforcement of the provisions of rules and regulations that require that plans for private sewage treatment works be approved by both the water supply authorities and the State Department of Health. This plan has worked out very satisfactorily as it provides the water works superintendent with knowledge of the location and type of treatment and furnishes a permanent record where the ownership changes and where in the future the new owner might have no knowledge of the location of such works in the case of any trouble arising.

Ordinarily water rules protecting New York State supplies secured from impounding reservoirs prohibit bathing, boating and fishing on the reservoir even though the supply be subject to filtration. When, however, supplies are secured from larger natural ponds and lakes the tendency is to divide the drainage area into zones for the purpose of graduating the severity of the rules in their application to

the different parts of the watershed so as to conform to the varying degrees of danger to the water supply. Bathing within 500 to 1,000 feet of water supply intakes is a common prohibition of such modified rules.

The only protection of some of the larger municipalities having their source of supply obtained from large bodies of water is chlorination. Although chlorination equipment in more recent years has been greatly improved and is more reliable than formerly when interruptions were frequent, the fact remains that chlorination is still subject to interruption and it naturally follows that every precaution should be taken to prevent pollution of the supply at least within a reasonable distance of the water supply intake in such bodies of water.

The recreational use of watershed land should be under strict supervision of a caretaker with satisfactory provision for the collection and disposal of garbage and sewage at a remote point off the watershed where it will be of no danger to the supply. On smaller watersheds such recreational use should be restricted, if possible, to a point below the water supply intake.

While the treatment of a water supply by a modern filter plant provides another protection against dangerous pollution of the raw water reaching the consumers without effective purification, it would be an unwise policy for water works authorities to advocate recreational use of watersheds without close supervision which will entail considerable expense on the part of the water works authorities. Therefore, water works authorities considering such recreational use of watershed lands must consider providing for adequate sanitary supervision and in some instances additional treatment may be required.

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Sanitation Design for Trailer Camps

By Eugene M. Howell

SO RAPID has been the development of "trailering," that it has taken the country unprepared. State and local ordinances are now being passed covering camp and sanitation requirements. Camps should be carefully planned before any construction work is started. Some of the important recommendations which are included in the Trailer Camp Rules and Regulations of the Colorado State Board of Health are as follows:

1. The location and general design should be of such nature that the approach to the camp and also the accesses to the stalls are of such construction that they can be entered from two directions.

2. The stalls should be level and well-drained, and of sufficient size —in Colorado, 900 square feet (20 x 45 ft. or 30 x 30 ft.), conveniently to take care of both trailer and automobile, and have sufficient space between the stalls.

3. The stalls should have a road on both ends or both sides (according to the plan of the camp), and have a minimum width of 20 feet.

4. The water used for bathing and culinary purposes should be approved by the State Health Department.

5. In a Class "A" Camp, there should be drains at each stall, connecting to an "approved" sewer.

6. The camps should have one flushing slop sink for each thirty (30) stalls, or fraction thereof.

7. There should be provided toilet units placed in separate compartments, inclosed with proper partitions, in the ratio of one toilet unit, for women, for every 12 stalls or fraction thereof; one toilet unit, for men, for every 20 stalls and one urinal for every 30 stalls or fraction thereof.

A paper presented at the Rocky Mountain Section meeting at Santa Fe, New Mexico, September 22, 1937, by Eugene M. Howell, Assistant Sanitary Engineer, State Board of Health, Denver, Colorado.

The toilet units should be the flush type sanitary units. Fly-tight privies approved by state health authorities may be used in unsewered districts.

8. One shower bath of approved construction should be provided for every 20 stalls for women, and one shower for every 20 stalls for men, or fraction thereof in both instances.

9. All waste water must be wasted into public sewers through approved sewer connections, or emptied into pails which then shall be emptied into a public sewer or connection with a septic tank.

10. Sufficient fly-tight garbage and rubbish receptacles should be provided, so placed as to be convenient for the use of camp and trailer occupants. Camps should provide for daily disposal of garbage. Incinerators may be used.

11. It is suggested to owners that there be an office conveniently located, also a filling station and recreational facilities.

It behooves every trailerite to help improve camps by constructive criticism. If camps now in use do not improve more rapidly, the use of trailers will be retarded.

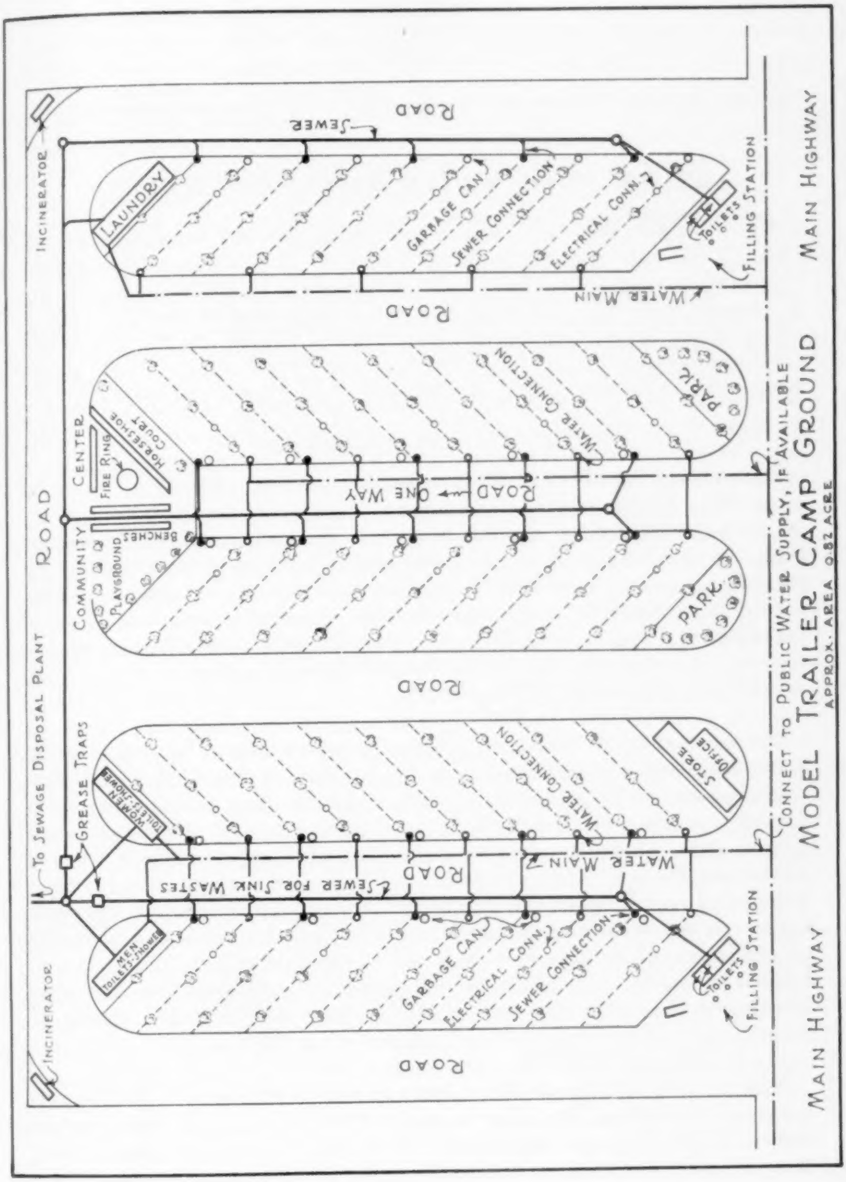
So much for factors of construction. Now, let us consider briefly a few of the problems that trailers bring to us.

The groups using these camps come from almost every station in life, and are generally uninformed as to camp sanitation. The use and care of trailer chemical toilets should be impressed upon the trailerite, as any unsanitary methods of disposal will ultimately result in laws forbidding their use.

The problem of cataloging contagious diseases and disease carriers is also a proposition which is confronting the epidemiologists. The sale and preservation of milk is one of the new trailer problems.

The use of trailers is very much on the increase—in Colorado the State Courtesy Patrol reports an increase in 1937 of 40 per cent over 1936. It can readily be seen that the growth of trailers depends upon the combined efforts of sanitary engineers, trailerites, and camp owners. Modern sanitary facilities are imperative.

Editor's Note: Although it is recognized that the water works executive is not commonly called upon to design or approve designs of trailer camps, a model design is reproduced herewith. This design is based upon a general plan approved by the Colorado State Board of Health, but certain elaborations have been made to show possibilities of the use of a public water supply, of supplying water taps and drains at alternate stalls, and of sewage disposal.



MODEL TRAILER CAMP GROUND
APPROX. AREA 0.82 ACRE

ABSTRACTS OF WATER WORKS LITERATURE

Key. **30:** 402 (Mar. '38) indicates volume 30, page 402, issue dated March 1938. If the publication is paged by issues, **30:** 3: 402 (Mar. '38) indicates volume 30, number 3, page 402. Material inclosed in starred brackets, *[ ]*, is comment or opinion of abstractor. Initials following an abstract indicate reproduction, by permission, from periodicals as follows: *B. H.—Bulletin of Hygiene* (*British*); *C. A.—Chemical Abstracts; P. H. E. A.—Public Health Engineering Abstracts; W. P. R.—Water Pollution Research* (*British*).

IMPOUNDING RESERVOIRS

Recreational Use of Water-Works Reservoir. ANON. Am. City. **53:** 6: 64 (Jun. '38). As part of its new, municipal water supply project, Springfield, Ill., acquired land for a large artificial reservoir and belt of marginal shore land. Special legislation authorizes leasing of portions of the shore land to reputable persons. Provisions in the leases protect city's rights and needs, appear to do likewise for the lessee and are designed to maintain lake surroundings of a high order. This novel plan is justified on the basis of protection of lake against pollution and conservation of shore property by proper development.—*Arthur P. Miller.*

Recreational Use of Ponds and Lakes in Relation to Use as Sources of Public Water Supplies. Health News, N. H. State Board of Health **16:** No. 9 (Sep. '38). A water supply, ample in quantity and pure, clean, safe and above any suspicion of reproach is of paramount importance to well being, health and very existence of all the people; being above and taking precedence over any of the benefits derived from recreational use of ponds and lakes. Proper function of chlorination is protective rather than corrective, and filtration, because of construction and operation costs, tends to impose heavy burden on tax payers of community. In N. H. in less than 5% of lakes, either in number or acreage, is bathing prohibited; but it is believed this and other methods of protection account for low typhoid rate in state.—*Martin E. Flentje.*

Exemplary Procedures in Water Engineering. EDITORIAL. Deut. Wasserwirtschaft **34:** 1 (Jan. '39). Characteristic of the newly created water authorities (in Germany) is the urgent desire to avoid tampering with natural landscape features and to have new construction harmonize to the utmost with its natural environment. Specifications for new power developments on the Günz river in Bavaria are quoted which include amongst other provisions the

following: (a) lower (flatter) slopes of embankments must be surfaced to suitable depth with fertile soil and planted with suitable young hardwood trees; (b) corners of ponds, etc., must not be abrupt, but rounded off as arcs of 300 feet radius; (c) on the water side of embankments, neither concrete nor bitumen may be used; tightness is to be secured by a layer of clay, over which, for protection, is laid gravel; at water level, rushes are to be planted in the gravel; (d) low dams of carefully adjusted heights are to be provided to ensure that the bottom will always be covered to a certain depth; (e) all growths must be removed from submerged surfaces, but all other existing growths are to be carefully preserved intact as far as possible.—*Frank Hannan.*

Water Conservation: A New Problem in Malarial Control. C. K. DeBusk. Texas State Jour. of Medicine **33**: 12: 826 (Apr. '38). Pioneers in Texas, through necessity, conserved water in rain barrels for themselves and in stagnant ponds for their live stock, and thus created additional breeding places for mosquito millions. There is justifiable apprehension on the part of some that this is about to be repeated on a large scale, due to the great water conservation program throughout Texas. Projects under construction and contemplated will create about thirty-five major reservoirs, with possibly thousands on the tributary streams. Backing the water up and spreading it out into the lowlands along the river valleys, may lead to an acute problem in malaria control, threatening to destroy the results of much time and energy which have been devoted to elimination of mosquitoes and their breeding places. Improper impoundment of water has been known to bring a return of malaria to sections that for years have been free of the disease. There is serious need for conservation of water for beneficial uses, including irrigation, and to protect the health of the people by preventing through proper conservation methods the pollution of these waters to an extent that will render them unfit for human uses. Conservation of surface waters is of extreme importance also from standpoint of underground supply. In all sections of the State there has been serious recession of the water level and in many sections it has fallen as much as 150′. If necessary antimalarial measures are taken, there should be no danger of increasing the extent of malaria or introducing it into new areas. Dams should have gates and flash boards to permit lowering water levels at the proper time. The basin should be cleared of all trees and brush should be piled and burned to prevent the flotage later. Trees and brush should be cut back sufficient distance from high water to permit inspection and to prevent these growths along shallow water edges from holding flotage. Recommended that water level be maintained at this max. elevation during winter and early spring in order that edges of reservoirs be flooded to prevent early growth of land vegetation; then later on in the summer the water level should be lowered quickly to strand flotage and larvae in the shallow areas. Wave action in the deeper portions should prevent anopheline breeding. Larvicides of various chemical content, oil, kerosene or other sprays, can be used in special locations. *Gambusia*, commonly known as "top minnows," are very helpful. In East Texas contemplated region-wide program will eliminate large portion of the swamp areas where water now stands for long periods and creates ideal mosquito-breeding conditions. Intended

to make mosquito control an integral part of the Sabine-Neches conservation district program and to embody preventive measures in the plans, construction and maintenance.—*P. H. E. A.*

Regulations Governing the Impounding and Maintenance of Impounded Waters in North Carolina. ANON. Health Bull. N. C. State Board of Health. **52**: 9: 11 (Sep. '37). The Board of Health adopted on May 5, '37, rules and regulations pertaining to impounding of water in connection with prevention and control of malaria. Before changing or constructing an impounding structure, a permit must be obtained from the Board of Health. The rules are accompanied by definitions of terms used in the legal wording.—*P. H. E. A.*

Underflow in Lee Lake, North Carolina. JACK L. HOUGH. Civ. Eng. **9**: 36 (Jan. '39). Underflow is the passage of turbid water beneath clear water in a lake or reservoir. Following the precipitation of nearly an inch of rain in one night marked underflow was observed in Lake Lee, the surface boundary between the clear and the turbid water being sharp. The temperature difference between the two waters was likewise marked, being distinguishable with the bare hand.—*H. E. Babbitt.*

The Passage of Turbid Water through Lake Mead. Discussion. Proc. A. S. C. E. **64**: 781 (Apr. '38). R. E. REDDEN: Greater specific gravity of flood water, due to suspended matter, given as reason for its not mixing with clear water of reservoir. Expected that future studies will show that flood loads from certain formations of particular geological age influence phenomenon of floods passing through reservoirs of clear water without intermixing. R. A. HILL: Experience at Elephant Butte Reservoir indicates that little is gained by passage of silt through Lake Mead. From the former reservoir, water carrying large quantities of suspended matter has been discharged for several days in almost every year, but total quantity of silt so removed is only small part of accumulation in reservoir. Geochemical chart showing data on salinity of the water above and below Lake Mead makes possible prediction of salinity of water below Lake Mead when its salinity above is known. Similar study, together with trial and error method, makes possible prediction of turbidity which will pass through lake. In general, data indicate that all silt not carried through when water entering lake contained less than 2% suspended matter. Indicate also that some of the calcium sulfate water which produced turbid flow was continuing to flow under the lake without its silt load. Must have been, therefore, mixing of the water characteristic of that entering the lake with other water which came in during spring floods. This passage of saline water along floor of reservoir borne out by other data. Indications are that the saline low-water flow of Colorado R. tends to flow through the reservoir and that spring flood waters tend to ride on top, affecting quality of water available for uses. *Ibid.* **64**: 919 (May '38). NATHAN C. GROVER AND CHARLES S. HOWARD: Have been instances of flows of turbid water through reservoirs under variety of conditions that cannot be evaluated because of lack of observational information. May be many instances of stratification of water in reservoirs due to differences in

density in which turbidity is not involved. There is an important and unexplored field of scientific research in relation to density currents and stratification in reservoirs. Where there is sufficient temperature range to cause "turnover" the yearly cycle of a large reservoir that carries over considerable depths of water from year to year appears to consist of: (1) annual turnover, and (2) inflowing flood water that contains less dissolved matter and is less dense than water already in the lake, and, therefore, spreads over and rests on it. Apparent mixing at times and failure to mix at other times is of interest in relation to density currents which may involve flows of water of such varying concentrations of dissolved salts as to be of concern to users.—*H. E. Babbitt.*

Decanting Muddy Lake Water. M. K. MILLARD. Eng. News-Rec. **121:** 310 (Sep. 8, '38). Recreational lake, 135 acres in area, created by concrete gravity dam built in '37 on Six Mile Creek, S. C., by Dept. of Agriculture, is subject to large flow of muddy water during each heavy rain. Observations showed that clay-burdened water flowing into lake dropped to lower level, leaving clear water on surface, and it has been found that by opening the 2-30" bleeder pipes 40' below crest, muddy water can be discharged, leaving lake clear. Procedure is ineffective only when heavy rains persist over long period, accompanied by high winds which create disturbing currents. ★[This procedure might be applicable to certain water supply reservoirs.]★—*R. E. Thompson.*

RUN-OFF AND FLOOD FLOWS

Influence of Forests upon Run-off. GEORG STRELE. Deut. Wasserwirtschaft **34:** 64 (Feb. '39). Opinions on the subject and, especially, upon how peak levels in flood time are affected, are most conflicting. Diametrically opposed views, alike based upon good evidence, are held by leading authorities. Very careful comparative experimental studies have been carried out by competent engineers in many countries, the chief, perhaps, of which have been Switzerland, United States, Czecho-Slovakia, and India. That rainfall is affected by elevation, increasing as elevation increases, is beyond question: but, of the alleged effect of forests in promoting increased rainfall, there is no convincing evidence. It is, however, an admitted fact that rainfall measurement tends to be more exact, and greater, when wind interference is less, as is the case in the forest. Fifteen known instances of copious rainfall in Europe are tabled, durations varying from 15 min. to 6 days, precipitation rate from 0.72 to 90 cu. meters per sq. kilometer per sec., total precipitation from 78 to 950 mm., and dates from 1822 to 1915. In addition to the measurable precipitation as rain or snow, an unmeasurable precipitation takes place as dew, hoar frost, and other forms of condensation; of this, the forests will enjoy a much greater share than the open country. Evaporation from the soil is, owing to free play of sun and wind, much greater in open country than in the forest; but evaporation from the vegetation is, on the other hand, much less. Amount of water which percolates into the soil and sub-soil is dependent upon many factors, such as slope of the ground, nature of surface and of vegetation, sub-soil conditions and degree of saturation there present, rate of

precipitation, rate at which snow melts, and other factors. Natural accumulation of loose litter of fallen needles and leaves in a properly conserved forest is the most favorable surface condition for entry of percolating water; but it is important that it be not trampled upon or otherwise disturbed. Unquestionable that, starting "all air-dry" and with other conditions the same in both, a given area of forest will absorb far more water than an equal area of open country; but once saturation has been attained, there seems to be no reason to expect that the further run-off should be any greater in one than in the other. The water retained in the litter and vegetation of the forest may be at the expense of underground storage, especially when prevailing rate of precipitation is moderate; so that it is only to be expected that forest clearing will, in some cases, raise the level of the water table with resulting increased flow in springs and development of swamps; while, in other cases, the reverse effects will be noticed. So, too, similarly, forestation may, in different localities and with different sub-soil and other conditions, exhibit results upon run-off the exact opposite of one another, owing to the inter-play of the numerous factors involved. The retarding effect of forests upon the melting of snow helps very materially to reduce flood peaks. In the case of rainfall, the initial retarding effect of the forest upon run-off is to be regarded as a temporary phenomenon; if the rate of precipitation be heavy, it may soon be exhausted; if light, it may continue for a long time. The flood danger from short heavy down-pours upon restricted areas is undoubtedly much reduced by forestation; absolute immunity from flooding does not seem attainable. Extensive forest clearings are always inadvisable; they do more harm than can be made good by reforestation. Young trees affect the run-off hardly at all; full effectiveness is reached only gradually and after many years. Especially is this the case on old rough pasturage, where it has been found that 50, or even 60, years must elapse before the desirable loose, water-retaining texture characteristic of properly conserved forest can be acquired. Usually more advisable, economically, to conserve existing forest areas in full efficiency than to plant new areas. This applies particularly to mountain country. It is unquestionable that, whether a river be large or small, its flow should be evened out to the utmost, to avoid, on the one hand, floods and, on the other, the many drawbacks of low water. As forest areas are distinctly conducive towards this result, it certainly behooves water control authorities not to underestimate their value. ★[A short treatise by a man who is evidently an expert.]★—*Frank Hannan.*

Weather Bureau's Mountain Snowfall Work. Merrill Bernard. Civ. Eng. **9**: 173 (Mar. '39). Methods for measurement of snowfall have progressed through the use of the snow stake, snow table, and the melting and weighing of the catch of an open rain gage, to the recently adopted snowfall station equipped with a battery of shielded, storage snow gages. The most satisfactory type of gage developed through investigations by the Weather Bureau is protected by an apron-like shield which closes in on the container when wind blows against it, thereby reducing the up-drafts that ordinarily disrupt the snow catch. The gage stores precipitation through the winter, containing anti-freeze solutions of calcium chloride from which evaporation is prevented

by an oil film. The increment of increase in weight of the gage between weighings represents the snowfall for the period, expressed in inches of water. There is believed to be a high correlation between the following determinable factors: (1) Amount of snowfall expressed in inches of water over the basin. (2) The chronological sequence of snowfall. (3) A concurrent record of temperature. (4) A factor evaluating ground surface conditions as an index of infiltration losses. Such information is applied in forecasting runoff from snowfall.—*H. E. Babbitt.*

A Radio Water-Stage Recorder. MAURICE E. KENNEDY. Eng. News-Rec. **122**: 91 (Jan. 19, '39). Brief details given of automatic device, recently developed for U. S. Geol. Survey by hydraulic dept. of Los Angeles County Flood Control Dist., for transmitting water stage readings from remote points by radio. Instrument can be set to transmit signals every hr. or day, and, when critical stage is reached, every 15 min. Two such installations on San Gabriel R. are visited only monthly to replace batteries and wind up clock wts. Device may also be employed to send readings over telephone circuits but radio transmission is considered more dependable during storms when wire lines might fail. District now has under construction automatic receiver that will record incoming stage readings on moving tape.—*R. E. Thompson.*

The Maximum Probable Flood and Its Relation to Spillway Capacity. S. M. BAILEY AND G. R. SCHNEIDER. Civ. Eng. **9**: 32 (Jan. '39). As a basic factor in the design of a reservoir project it is frequently necessary to make a rough estimate of the spillway capacity required. The so-called "rational" method, whereby isohyetals are transposed, a run-off factor is determined, and a hydrograph is constructed, has proven satisfactory. An important condition in the application of this method is the maximum probable rainfall. The estimated maxima are based on the known maximum precipitations which have occurred in a few places in this country. Isohyetal maps, showing maximum probable precipitation over the eastern portion of the U. S. are given in the article. In estimating the maximum run-off from the rainfall the per cent run-off may approach 100 or be as low as 30. The engineer must depend largely on judgment and experience in such areas. In estimating spillway capacity: (1) select the maximum rainfall from the charts given in the article, (2) determine the expected run-off from the product of the rainfall and the maximum run-off factor to be expected, (3) construct the hypothetical hydrograph of the maximum probable flood, or construct a unit-graph for a storm period of one day or less, (4) complete outflow curves for assumed spillway lengths, (5) route the flood through the reservoir, making reasonable assumptions as to condition of outlets and pool elevation at beginning of the flood, (6) fix the crest elevations of the dam for each pool elevation as the sum of the maximum pool elevation and height of waves, and (7) plot a curve showing spillway length against crest elevation of dam. From this the economical combination of spillway and dam can be determined.—*H. E. Babbitt.*

Actual Duration of "One-day" and "Two-day" Rain Storms. CHARLES W. SHERMAN. Civ. Eng. **9**: 179 (Mar. '39). It is interesting to note that irre-

spective of the classification adopted the average lengths of significant storms are nearly the same, that is: for 1-day storms, 13–14 hr.; 2-day storms, 21–31 hr.; 3-day storms, 43–47 hr.; 4-day storms, 71–74 hr.; 5-day storms, 83–84 hr.; and 6-day storms, 112(?) hr.—*H. E. Babbitt.*

Construction Design Chart—Runoff in Farming Country. JAMES R. GRIFFITH. W. Cons. News **13**: 449 (Dec. '38). A nomographic chart is given for graphical solution of formula $Q = 0.25\ M^{\frac{3}{4}}\ S^{\frac{1}{4}}$, where Q = cu. ft. per sec.; M = acres drained; S = av. slope of ground, ft. per 1000′. For determining runoff in farm areas. Max. rainfall intensity of 1″ per hr. assumed. Prepared especially for detng. culvert sizes.—*Martin E. Flentje.*

WATER-BORNE DISEASE

The Dissemination of Typhoid and Paratyphoid by Water. R. RADOCHLA. Erg. Hyg. (Berlin) **21**: 46 ('38); Zbl. ges. Hyg. (Berlin) **42**: 609 ('38). A collection, from the literature of all countries, of information on epidemics of typhoid and paratyphoid caused by water. Epidemics are described in two groups. The first deals with those whose cause is attributed to water but where the presence of *B. typhosus* and *paratyphosus* was not proved. In the second and smaller group the bacteria were detected. Author also deals generally with water as a source of infection, discusses other gastro-intestinal diseases of uncertain origin, and classifies epidemics of typhoid and paratyphoid into seasonal and geographical groups. The month of maximum occurrence appears to be Sept. and the countries where epidemics are most frequent are Germany, France, and the U. S. A. A list of 326 references to the literature is given.—*W. P. R.*

Epidemics of Typhoid Fever. H. CAMBESSEDES. Ann. Hyg. publ. (Paris) **16**: 272 ('38). Discusses incidence of typhoid fever in children and adults in normal times and during epidemics. In two water-borne epidemics a high percentage of cases occurred among children under 15, whereas normally more cases occurred among people of 31 to 40.—*W. P. R.*

A Typhoid Fever Outbreak Attributed to Use of Contaminated Well Water. ANON. Health News, N. Y. State Dept. of Health **15**: 25: 105 (Jun. 20, '38). "Interesting sequence of events resulted in discovery of a recent outbreak of typhoid fever among persons traveling by bus between Chicago and N. Y. State. Routine investigation of 5 cases of this disease in N. Y. State in widely separated localities revealed fact that all these persons had traveled by bus between Chicago and various points in N. Y. during the period of probable incubation. Also learned that 4 recent cases of typhoid fever in N. Y. City, and 2 cases of this disease in Chicago gave similar history. These cases apparently are part of a recent outbreak of typhoid fever in Indiana. (See also abstract J. A. W. W. A. **30**: 1424 (Aug. '38)). Indiana State Dept. of Health has determined that approximately 40 cases of typhoid fever occurred among patrons of an inn in that state. Found that the water used at this inn had been contaminated as result of broken sewer which was within 5′ of well used as water supply. Fluorescein flushed through toilet system

entering this sewer was recovered within 5 min. in the water supply. Correction of this condition immediately made. Inn in question used as a luncheon stop by various busses traveling between Chicago and N. Y."—*P. H. E. A.*

Typhoid Carriers. H. PEETERS, A. CHARLOTTE RUYS AND C. H. EPHRAIM. Nederl. Tijdschr. v. Geneesk (Netherlands) **82**: 3741 ('38). Since '14 all cases of typhoid fever have been investigated epidemiologically. By this is meant a concentration of attention on individuals who are under suspicion in the case, or who by their contact with the patient might be carriers. A well equipped bacteriological laboratory is a necessity for the completeness of any such scheme. It was not always possible to obtain the consent of individuals to examination of feces. In this investigation the media which were used, and which proved better in combination than separately, were Endo, the tetrathionate medium of L. Muller and the Wilson-Blair medium (J. Hyg. **26**: 374 *and* **31**: 138). In the course of years 50 typhoid carriers were discovered, 18 men and 32 women; six of these have died; four were cured by cholecystectomy and six ceased spontaneously to be carriers. Details are given of the finding of carriers, following the notification of a case of typhoid. Of the 34 carriers now known and living, 17 have been under regular control by examination of urine and feces, while the remaining 17 have withdrawn from control either because of change of residence or by refusal to co-operate. One typhoid carrier has refused further examination because his household and family are immunized. It is to be noted that with few exceptions persons recognized as carriers have ceased to cause infections after their recognition.—*W. P. R.*

The Probable Typhoid Carrier Incidence in Mississippi. A. L. GRAY. Am. J. Pub. Health **28**: 1415 (Dec. '38). Presents the problem of typhoid fever control and what may be expected in Mississippi. The incidence of typhoid carriers in an area is dependent on the past prevalence of the disease in that area. Mississippi, with a population of slightly over 2 million has experienced typhoid fever death rates varying from 342 per 100,000 in '20 to 77 in '37. A random survey of 18,577 persons in 16 counties revealed 1,547 case histories of typhoid; indicating 183,230 persons in the state who have had the disease. Of 244 proved cases, 3.3% became permanent carriers. Hence, there must be approx. 6,000 carriers in the state or 288 per 100,000.—*H. E. Babbitt.*

A Dog as the Probable Source of Infection in a Small Outbreak of Paratyphoid-B. J. CASPERSEN. Ztschr. f. Hyg. u. Infektionskr. (Ger.) **120**: 611 ('38). In the course of a few days six cases of Paratyphoid B occurred in one family and its immediate neighbours. Three other persons harbored the bacillus in the feces without clinical signs of illness. The dog owned by the family had just previously suffered from a gastro-enteritis with profuse diarrhea. Its sera was tested on five occasions against H and O suspensions of *Bact. paratyphosum B.* On the first test it gave agglutination with both suspensions to moderately high titres which subsequently fell. Such results were not found with 23 other tested dogs. Concluded that the dog was the probable source of these very localized infections.—*B. H.* (*See also* J. A. W. W. A. **30**: 853 (May '38)).

Typhoid Death Rate Drops. Anon. Calif. Dept. of Pub. Hlth. Weekly Bul. **17**: 26: 102 (Jul. 23, '38). Last year typhoid mortality in California reached its lowest point in history of the state. But 59 deaths from the disease with an unprecedented rate of 0.9 per 100,000 population. Thirty years ago, more than 30 out of every 100,000 residents of California died of this disease. In many counties of the state typhoid is a rare disease. In others, it occurs regularly, each year, not because public methods of control are not applied, but because of the failure of individuals to observe the common rules of hygiene. As long as irrigation ditches are used for domestic sewage disposal, and at the same time, for domestic water supply, typhoid will prevail. The same applies to surface streams in some districts of the state. It is not always easy to obtain the cooperation of some of the foreign-born races in the observance of preventive measures. Only efficiently conducted public sewage disposal systems and water supplies are, of course, permitted to operate in California, and water-borne outbreaks of typhoid seldom occur. The carrier problem is still present but does not cause the acute anxiety that it did a few years ago. Methods of public sanitation show great improvement over previous years. Nevertheless, the control of this disease requires constant vigilance even though its prevalence be reduced greatly. A considerable number of cases is brought into the state each year, and carriers are responsible for an unknown number of new cases. Failure to maintain ordinary domestic sanitation upon individual premises is also a factor in the typhoid fever situation. While the disease will never be eliminated entirely, it would seem that it has now reached its minimum in California.—*P. H. E. A.*

An Anti-Typhoid Campaign. J. M. Cruickshank. J. Roy. San. Inst. (Br.) **59**: 180 ('38). The campaign described was carried out in Nassau in the Bahamas (pop. 20,000) between '29 and '38 with result that annual typhoid incidence fell from 108 cases in '27 to 11 in '37. In '28 a chlorinated pipe-borne water supply was installed but this was only available for a small section of the community and moreover only those receiving this supply could adopt the water-borne sewage disposal system. The bulk of the pop. therefore remained in unsatisfactory environment and in '30 wholesale inoculation was initiated. Employees at the city water-works are examined to exclude carriers of typhoid or any with amoebiasis. Public standpipes (hydrants for general use—*Ed.*) being installed each year at strategic points, food in shops is compulsorily protected in show-cases, and officials make inspections to see that the regulations are adhered to.—*B. H.*

The Typhoid Epidemic at Strausberg and Its Bearing on Typhoid Elimination. T. Wohlfeil and Manke. Veroff. VolksgesundhDienst. **50**: No. 3; Wass. u. Abwass. **36**: 58 ('38). Found at Strausberg, France, that provision of a central water supply was not sufficient to prevent typhoid. A central drainage and sewerage system was of greater importance but both measures are incomplete until all dwellings are connected with the central systems. In places where local authorities cannot compel all inhabitants to use the central systems they should insist that all wells are regularly tested and examined. Although improved sanitation plays an important part in reducing typhoid

there will not be complete success as long as it is possible for carriers to infect milk and foodstuffs. Employees at milk factories and water works should undergo medical examination at least twice a month.—*W. P. R.*

Sanitating Illinois. ANON. Illinois Health Messenger **10**: 12, 84 (Jun. 15, '38). Taking as a practical definition of "sanitation" the "prevention of return to the mouth of matter excreted from the body," has prevented a greater volume of illness in Illinois, and perhaps generally, than any other class of preventive effort. Sanitation of one water or milk supply affects immediately a large number of people, whereas vaccination, for example, or bedside disinfection, affects only one or a few people at most. Since '34, typhoid fever has caused less than 100 deaths annually in Illinois, compared with upwards of 500 annually prior to '19, and upwards of 1000 annually prior to '10. Infantile diarrhea has been responsible for less than 500 deaths annually since '34, compared with upwards of 2000 annually prior to '29, and 3000 annually prior to '22. This also in spite of a steady increase in the population of the state. Furthermore, there are about ten cases of illness of these diseases for each death. Sanitation has also substantially decreased septic sore throat and scarlet fever; easily spread through contaminated milk. Public water and pasteurized milk supplies have had major attention. More recently, the State Dept. of Health has given attention to private water supplies and toilet facilities. Between Jul. 1, '35, and Mar. 31, '38, 32,306 sanitary privies have replaced insanitary privies which might have polluted water supplies through seepage or food supplies through flies. While constructing sanitary privies in unsewered districts, the Department's stream conservation activities have caused sources of pollution to be abated along hundreds of miles of waterways. Thus healthful environment conditions are being extended to individual homes on a scale never before possible.—*P. H. E. A.*

Water-Borne Sonne Dysentery. ANON. Health News, N. Y. State Dept. of Health **15**: 24: 99 (Jun. 13, '38). "Seventy-one cases of gastro-intestinal illness are known to have occurred between May 17 and May 31 in two contiguous villages in Albany County. Symptoms consisted of fever, nausea and diarrhea, generally with sudden onset. The more severely ill patients exhibited blood in the stools. Fecal specimens submitted from three persons during the acute stage yielded dysentery bacilli of the Sonne type. On investigation the one factor found common to all cases was the use of water from the system which supplied both villages. The water supply for these villages is secured from a creek and treated by chlorine but not filtered. Interruption in chlorination of the water was reported to have occurred on at least one occasion preceding the outbreak, resulting in the delivery of untreated water to consumers. Coincident with the failure, a heavy rainfall also increased pollution of the source of supply."—*P. H. E. A.*

A Milk-borne Outbreak of Gastro-Enteritis. ANON. Health News, N. Y. State Dept. of Health **16**: 9: 33 (Feb. 27, '39). Epidemiological study of recent gastro-enteritis outbreak affecting approx. 100 of 200 inhabitants of Dutchess county institution was traced to milk supply. While water was found to have

potable driven well supply cross-connected to potentially contaminated surface supply, investigation showed less than half of patients used non-potable water and water was deemed safe from bacterial analysis results and sanitary survey. Water supply conditions corrected and dairy herd and equipment sold.—*Martin E. Flentje.*

Report on an Outbreak of Gastro-Enteritis. With Note on the Bacteriophage Test by J. Morison. B. R. Nisbet. Med. Officer **59**: 87 ('38). During last five months of '37 gastro-enteritis assumed high prevalence in Kilmarnock (Scot.), total of 162 cases occurring during that time; period of maximum prevalence being during the 3 weeks ending Sept. 11. Water supply of the town derived from two sources, and the distribution in area and numbers suggested a water-borne infection from the Craigdunton supply, which is unchlorinated. Bacteriological examination in two cases disclosed *Bact. dysenteriae* Sonne in stools, in a third case this diagnosis was supported by the bacteriophage test, whilst in the house of a family in which there were three probable cases the drinking water in a pail gave a bacteriophage reaction indicating gross infection. The last infection may have been caused by the patients or alternatively the patients may have been infected by the water, but dysentery bacteriophage was demonstrated in samples from the kitchen tap and not in control samples. In 4 samples taken from the main between this tap and in the filter plant all but one showed dysentery bacteriophage only on enrichment, suggesting passage of bacteriophage but not viable bacilli in any numbers through the filters. Stools of all men in filter plant showed presence of bacteriophage, but two were picked out by the strength of reactions and both found to have been ill and one to have suffered from diarrhoea in July or Aug. One of these men had more opportunities than the others to foul the water. Craigdunton supply comes from Loch Goin and water from latter gave strong reaction indicating a active pollution with dysentery. Of excreta collected round the Loch, that of a seagull showed very active dysentery bacteriophage. Habits of certain species of gulls would explain presence of the bacteriophage in this gull's excretion, and suggests possibility of dysentery infection being carried to inland reservoirs by gulls, and its distribution through an unchlorinated supply. Further examinations of water and feces from gathering grounds failed to reveal dysentery bacilli. According to Morison use of tests for bacteriophage in detecting specific infections depends on intimate association of certain bacteriophages with certain bacilli.—*W. P. R.*

Paris: Office International D'Hygiène Publique. *Summary of Proceedings at the May, '38, Session of the Permanent Committee.* Anon. Bul. of Hygiene (Br.) **13**: 685 (Sep. '38). *Bacillary Dysentery.* p. 690. Number of cases in Great Britain continues to increase: in '34 there were 103 fatal cases in total of 763, 116 fatal of 1177 in '35, 1333 total and 87 fatal in '36, and total of 4068 cases in '38. Bacilli most often concerned were the Sonne type or the Flexner type in one of its 5 forms; Shiga's bacillus rarely met in Gt. Britain. In U. S. dysentery has been observed mainly in southern regions. U. S. Public Health Service carrying on research; in Va. over 4 yr. period incidence of 1.77% of bacteriologically verified bacillary dysentery: Flexner and Sonne were found

but no case of Shiga. In Calif. in 922 examinations of diarrheal stools, 38 Shiga, 518 Flexner, 117 Hiss Y and 249 Sonne were found. In Canada dysentery less frequent in '37 than in '36.—*Martin E. Flentje.*

An Explosive Epidemic of Dysentery in Omuta City, Kyushu, Japan. ANON. J. Pub. Health Ass. (Japan) (Jun. '38). *Report by Acute Infectious Disease Prevention Bur. of Dept. of Health and Social Affairs* (Oct. 25, '37). In a population of 110,000 an epidemic of dysentery believed due to contamination of water supply caused 11,000 cases with 500 deaths. Daily cases from Sept. 25th. were 261, 1,920, 2,662, 2,038, 1,523, 833, 500 and then a slow decrease lasting till end of Oct. Evidence incriminating water supply includes wide area over which cases were spread, absence of cases in parts not consuming the water, and explosive nature of the outbreak. Water supply drawn from six wells and investigation showed that at one the watchman and his family were excreting bacilli identical with those recovered from patients in the city. A child in this family had suffered from diarrhoea from Sept. 19th. to 25th. Probable that he suffered from dysentery and conditions were such that water with which the patient's soiled clothes were washed had easy access to the well. The methods of filtration at the waterworks were admittedly inadequate and general contamination of the supply would not have been difficult.—*W. P. R.*

Is Goiter Water Borne: CECIL M. STANBURY. W. W. Eng. **92**: 302 (Mar. 15, '39). Writer states that for over two thousand yrs. popular verdict has been that water was the carrier of goiter agent and that it is illogical to assume that such a general and age-long belief should be without some foundation. Many theories about goiter presented but none fit all conditions. Article presents findings of Dr. André Crotti of Columbus, Ohio, who feels that only a *contagium vivum* can explain satisfactorily endemic goiter. Goiter is dependent on the situation of residence; where goiter incidence is highest, the topographical conditions necessary to produce goiter are also highest. In expts. lasting since '10, Dr. Crotti has been able to isolate an organism from goiter specimens removed on operating table—organism isolated most likely belongs to genus *Alternaris*, of the order *Hyphomycetes*. In dogs, cultures of organism produced an incidence of 66% goiter, and recovery of the goiter fungi, positive in 71.4%. By feeding iodine at the same time of innoculation moderate rate of goiter decline noted, this not at all conclusive. Water samples taken at random in Ohio and W. Va. produced golden-body of fungi same as found in fresh and cultivated goiter material. Further tests on water from all over world showed absence of fungi from locations where no goiter present, from other locations fungi found in filtered, spring, and well waters. Dr. Crotti stated to have proven a *contagium vivum* the true primary causative of goiter by systematic research. Goiter fungus from fresh goiter material under dark field illumination first seen as tiny body, of unusual brilliance, round or oval in shape, surrounded by golden halo and travelling rapidly in tumbling motion. Other bodies also found are granular and deep gold and others bluish-white granular. No flagella seen; size from about 1½ microns to visibility.—*Martin E. Flentje.* (As suggested in an editorial in Water Works Engineering, which journal carried the above article, the findings and conclusions of the author

need to be confirmed by independent investigators, so that their validity may be more adequately demonstrated.—*Ed.*)

STERILIZATION

Modern Practice in Water Chlorination. L. H. Enslow. Eng. Cont. Rec. **51**: 33: 23 (Aug. 17, '38). A brief discussion. Prechlorination provides a high factor of safety. Ammonia-chlorine treatment, by allowing the carrying of higher chlorine residuals into mains without danger of chlorinous tastes, reduces dead-end complaints and main flushing, controls growths of such organisms as *Crenothrix* in mains and suppresses biological tuberculation. Most modern and reliable practice in taste control is the use of powdered activated carbon in conjunction with prechlorination. Chlorine is also used for oxidizing iron and manganese and for cleaning filter sand. New scheme of coagulant production involves passage of chlorine water through tower filled with scrap iron, the solution of ferric chloride in weak chlorine water produced effecting, in one operation, coagulation and prechlorination.—*R. E. Thompson.*

Policy of Chlorination of Chalk Wells. Metr. Water Board (London). Anon. Off. Cir. Br. W. W. Assn. **20**: 544 (Aug. '38). Report of M.W.B. Water Exam. Committee states that slight departures of M.W.B. well waters from standard of 100% negative coliforms in 100 ml. are immediately corrected by chemical and engineering means and are of little significance. Research indicates that atypical coliforms give early warning of less secure conditions associated initially with typical coliforms in 100 ml. Deep wells in chalk in Kent in no case show even lightest pollution (i.e. consistent typical coliforms in 100 ml.) and only occasionally atypical coliforms in 100 ml. Typhoid carriers working in wells would introduce probability of infection but with moderate chloramination public would be safeguarded unless pollution is gross. Stand-by chlorination apparatus has been available of late to treat supply from well in which men working when water not pumped to waste. For last 2 years stools and sera of men known to have been in association with enteric have been examined, and there have been two cases where clean bill of health has not been proved. Dejecta of men who have contact with water are subjected to routine bacteriological examination. Although some reasonable risk to consumers must be accepted by water undertakers and in view of diversity of paths and modes of infection every remote contingency cannot be prevised, yet protection of all well waters would be enhanced by chloramination. Adequate chloramine dosage for good well water would not be effective with sudden access of oxidisable matter, high bacterial infection or sewage invasion. Consequently with chloramination early evidences of pollution as shown by atypical coliforms in 100 ml. would be masked and yet ordinary dosage would not afford protection against massive infection. Summing up the Committee recommend that M.W.B. endorse principle of chloramine treatment for all wells pumped direct into supply saying that it may enhance reputation of M.W.B. and remove any possibility of extremely remote pollution, but that such a measure is insurance against improbable contingencies.

Kent wells between '05 and '33 gave yields above 93% absence of coliforms in 100 ml.—*W. G. Carey.*

Water Filtration vs. Chlorination. J. Am. Med. Assoc. **107**: 18: 1474 (Oct. 31, '36). In general, if a community had to depend for health protection on filtration alone or chlorination alone, chlorination would probably be chosen. Filtration clarifies a water and it is the general practice wherever large supplies are filtered, to chlorinate also as a safeguard. It is pointed out that any method of water treatment requires continuous expert supervision. A comparatively recent study of water borne diseases has shown that from '20 to '29, approximately 40% of the outbreaks were because of defects in collection, treatment, storage and distribution and not to the pollution of raw water.—*P. H. E. A.*

Chlorinating Plant Designed for Maximum Safety. H. G. SHOCKLEY. W. W. and Sew. **85**: 1109 (Dec. '38). Due to proximity of residential section, New York City chlorination plant is provided with unusual precautions against chlorine escape. These include large exhaust fan, pressure well for isolation of leaking cylinders and reclamation of leaking gas, provision for flooding pressure well with water, caustic soda, lime, or ice. Detail drawings of pressure well are included.—*H. E. Hudson, Jr.*

Sterilizing Small Supplies. ANON. Can. Engr. **74**: 21: 18 (May 24, '38). Brief description of water supply system of paymaster Consolidated Mines, South Porcupine, Ont. Supply derived from MacDonald Lake, 12" wood stave pipe line delivering water from lake to pump house. 6" main supplies mine and 4" line the residences and camps. Overhead tank provides 75' head on mains and at base of tank a water-power-driven hypochlorinator was installed on 4" line, through which 25,000–50,000 gal. of water flows daily. Hypochlorinator has capacity of 60 gal. of hypochlorite solution per day and dosage is regulated in proportion to flow by meter which forms part of unit. Machine consists essentially of diaphragm pump constructed of corrosion-resistant material. Control of pump may also be effected by small electric motor and either manually or semi-automatic. Smaller supplies have been neglected in past due to lack of suitable equipment and greater attention can now be given to this potential source of water-borne disease.—*R. E. Thompson.*

Sterilization of Spore-Bearing Bacteria in Water Supplies. JOHN N. McDONNELL. Am. J. Pharm. **110**: 346 ('38). Spores of *B. subtilis* group of organisms exist in the natural sources of the water supply, a high percentage passing through the sand filters and the later chemical treatment unchanged so that they are to be found in ordinary tap water supplied by the filtration plants. Strengths of Cl ranging up to 30 p.p.m. have no effect on spores, and the spores develop into the vegetative forms and multiply when the Cl content drops below the bacteriostatic level. The chloramine process offers a means of disinfection for waters contg. spore-bearing bacteria, and (1) 10 p.p.m. of NH_3

with 30 p.p.m. Cl sterilizes immediately; (2) $6\frac{2}{3}$ p.p.m. NH_3, followed by 20 p.p.m. Cl, sterilizes within $\frac{1}{2}$ hr., and (3) $3\frac{1}{3}$ p.p.m. NH_3 and 10 p.p.m. Cl sterilize in an interval of between 1 and 2 hrs. By preceding the chloramine treatment (in effective strength as given above) by alum as a coagulant in strength of 1 g.p.g. the effectiveness was increased. Possible to reduce the NH_3 strength to 1 p.p.m. followed by 3 p.p.m. of Cl as a result of this coagulant, to produce effective disinfection in the same time and it was noted that: (1) Odor and taste at this point were not noticeable. (2) This ratio of alum, NH_3 and Cl was considered most practical for application at filter purification stations, if prechlorination is practiced with coagulants in the rapid sand filters. This ratio of chemicals, however, increased the necessary contact period to a four-hr. limit. 41 references.—*C. A.*

The Action of Some Disinfectants on Various Bacteria. R. HANNE. Arch. Hyg. Berl. **119**: 125 ('37). Experiments carried out to determine period of survival of bacteria in various concentrations of the disinfectants Zephirol, Sagrotan, Baktol, chloramine, Karbol, Lysol, cresol soap solution and Trioform-"Goldsiegel". Bacteria of the coli-aerogenes group and other groups were tested. The results are shown in tables and are discussed. Except when Trioform-"Goldsiegel" was used, the effect of each disinfectant was approximately the same on all members of the coli group. For complete destruction of *Esch. coli* the strength of disinfectant had to be greater than in case of any other bacteria. Other bacteria tested varied considerably in their reactions to each disinfectant.—*W. P. R.*

Chlorination Terms. ELLIS K. PHELPS. Pub. Wks. **69**: 12: 14 (Dec. '38) and **70**: 1: 39 (Jan. '39). Title indicates contents of complete and informative article on chlorination terms, definitions, description of equipment and functions.—*Martin E. Flentje.*

The Purification of Water Supplies by Units in the Field. E. F. W. MACKENZIE. J. roy. Army med. Cps. **71**: 289 ('38). Describes and discusses methods for purification of water supplies under field conditions. Modern conditions require a method which will provide a safe and taste-free water with least possible delay. Investigations of a method of producing satisfactory water in 15 min. are described. Advantages and disadvantages of chlorination and ammonia-chlorine treatment are discussed. Taking into account the efficiency, speed and adaptability of the method and the stability of the materials, it appears that superchlorination followed by dechlorination with sodium thiosulfate is most satisfactory process. Details are given of the results of treatment by this method of a number of polluted waters. The process has been found to provide a wider margin of safety than other processes. Taste troubles are of rare occurrence and tastes present in the raw water are frequently improved. Experiments showed that, with dechlorination, the amount of chlorine used might be increased as far as 50 p.p.m. without causing taste. Effect of the chlorine on waters infected with the cercariae of pathogenic schistosomes is discussed.—*W. P. R.*

Allergy to Chlorine. ANON. J. Am. Med. Assoc. **111**: 1788 (Nov. 5, '38). Following quoted from reply to a query regarding allergy to chlorine in bath water: "Allergy to chlorine, while not definitely accepted, has been reported. Duke (J. Allergy **3**: 495 (Jul. '32)) had a patient, a physician, who acquired coryza, cough and asthma from use of Dakin's solution, and from the chlorine gas which escaped from diluted solution of sodium hypochlorite. Chlorinated water caused wheals in this patient. Passive transfer of this hypersensitivity to chlorine was not successful. Duke believes that this type of allergy is similar to that found in physical allergy. Watson and Kibler (*Ibid.* **5**: 197 (Jan. '34)) reported a case in which chlorine in drinking water was apparently the cause of asthma and colitis. The patient became worse when drinking chlorinated water and was entirely relieved on changing to distilled water. In discussion which followed presentation of this paper, Eyermann stated that he had relieved two patients of intractable urticaria by use of distilled water. These patients had failed to respond to ordinary elimination diets. Milton Cohen discussed the case of a chemist who had coryza from the inhalation of platinum chloride. Dutton (*Ibid.* **6**: 477 (Jul. '35)) reported a case in which severe eczema resulted from drinking of ordinary tap water; when distilled water was substituted on numerous occasions, the eczema cleared up quickly each time. Author concluded that some allergen or other substance in the drinking water was the etiologic factor but did not specify what this substance was. From these reports it seems evident that the patient under consideration must avoid contact with chlorinated water. Apparently contact with the water is sufficient. If there is a possibility that drinking such water causes urticaria, distilled water should be substituted.—*J. H. O'Neill.*

Behaviour of Chloramines in Swimming Pool Sterilization. C. H. CAPEN. Baths & Bath Engng. (Br.) **4**: 33, 94 ('37). In baths in which alum is added to the water before filtration and chlorine is added as a sterilizing agent, irritation to the eyes of bathers is often due to alum and not to chlorine in the water. Tests indicated that the human eye may be irritated by alum in a concentration equivalent to 0.1 p.p.m. Al and that it is acutely affected by a concentration equivalent to 0.5 p.p.m. The efficiencies of chlorine and chloramine as sterilizing agents for swimming bath water are compared.—*W. P. R.*

Selecting the Most Chlorine-Resistant Paints. A. P. POLOZOV AND R. P. GOVOROVA. Mem. Inst. Chem. Tech., Acad. Sci. Ukrain. S. S. R. No. 9: 211 (in English, 236) ('38). $PbSb_2O_6$ showed high resistance to wet and dry Cl. Addn. of 20% $BaSO_4$ is not harmful but further addn. of $BaSO_4$ lowers resistance. Use of $PbSO_4$, $BaCrO_4$ and $Ni_3(PO_4)_2$ with 40% $BaSO_4$ is recommended. —*C. A.*

Water Treatment. Purification by Electrically Generated Ozone. ANON. Electrician (Br.) **120**: 511 ('38). Deals briefly with use of ozone treatment compared with chlorination for disinfection of water. Chlorination has

disadvantage that excess chlorine causes tastes, and on exposure to sunlight the solution of chlorine is converted into a dilute solution of hydrochloric acid. Excess ozone however passes freely from solution and any small quantities which may be absorbed by the water are rapidly reduced to oxygen under influence of sunlight. Ozone can be generated electrically in several ways. Generation of nitrous compounds which are unpleasant to smell and taste may be prevented if temperature of the air is kept low and the air is comparatively free from moisture. Diagram of an ozone treatment plant is given. Initial cost of an ozone treatment plant is higher than that of a chlorination plant but operation costs are lower; if ozone is applied at rate of 100 grams per 10,000 gal. per hr. and 1 kw. hr. produces about 50 grams of ozone, the total cost of treating 10,000 gal. is 1½d. (approx. 3¢) with electricity costing ½d. per unit. Experiments being made to develop more efficient ozone generators. Use of ozone treatment in mineral water factories and swimming baths is mentioned.—*B. H.*

Bacteriological and Hygienic Considerations Arising from Experiments with the Electrokatadyn Method of Disinfection. S. Hoffmann. Arch. f. Hyg. u. Bakt. (Ger.) **120:** 147 ('38). Krause's method of sterilization by the electrokatadyn process (EKV) consists of the introduction of silver ions into a fluid from silver electrodes connected to an electric battery. The electrodes are kept in constant motion by a hand machine to produce even distribution of ions, or, in case of water sterilization, the electrodes are suspended in a vessel through which water is passing continuously. In order to be effective, the positive silver ions must come into contact with the negatively-charged bacteria. The amount of silver passing from the electrodes into solution follows Faraday's Law and the dosage is estimated in terms of gamma, that is, 40 gamma are equivalent to 2.4×10^{14} silver ions per ml. Experiments were performed by the author, who found that a reliable disinfecting dose for the local drinking water was 350–400 gamma per liter. Little difference between the sterilizing effects of silver nitrate solution and EKV. Freshly isolated organisms were more resistant than stock cultures, and the greater the concentration of microbes the longer the time required to effect sterilization. The effect was not maximal until after ½ hr. and it was found best to wait an hour for optimal results. Within limits, the higher the ionic concentrations the quicker the disinfection, minor differences noted with lower concentrations also being eliminated. As long as free ions are present the fluid remains sterile but certain substances hinder the EKV effect by taking up the silver ions. For example, chlorides, iron or hydrogen sulfide in water, reduce or "deviate", and the organic substances urea, peptone, broth or blood serum also decrease the number of available ions. Advantages of the method are that it is odorless, overdosage is impossible, all forms of vegetative bacteria are killed and spores prevented from germinating. Amount of silver dissolved during the process is too small to menace health; drinking 100 ml. of katadynized water each day for 60 yrs. would lead to ingestion of only 0.8–0.9 grams of silver. Disadvantages are slightly greater expense than chlorination and water must contain but little organic matter, chlorides, iron or sulfides in order for a reasonable EKV dose to be effective. ★[This is a very serious deficiency from

the practical viewpoint.]★ Its application to food-preservation, such as tinned or bottled fruit, is not feasible but Author believes it has possibilities for preserving sausages, maintaining them palatable and innocuous for a few days longer than is usual.—*B. H.*

The Manufacture and Use of "Activated" Ice Made Antiseptic by the Oligodynamic Action of Silver. ANON. Riv. Freddo (Mar. '38); Génie civ. **112:** 504 ('38). Ice prepared from water with a strong oligodynamic action can be added to liquids used for drinking or can be used for preserving foodstuff, such as fish or meat, placed in contact with it. Moisture from the atmosphere condenses on ice and cold food, carrying bacteria with it. "Oligodynamic ice" will destroy these bacteria. To disinfect water or ice 50 mg. of silver per cu. meter are sufficient. To prepare concentrated "oligodynamic" or "activated" water or ice 400 mg. per cu. meter are required.—*W. P. R.*

COAGULATION AND CHEMICAL FEEDING

Influence of Presedimentation in the Coagulation of Water from the River La Plata. C. E. GIETZ, J. M. BACH AND C. PEREYRA. Bol. Obras Sanitarias Nacion (Buenos Aires). **2:** 403 (Apr. '38). Proposed construction of large raw water reservoirs on bed of La Plata R. in order to protect Buenos Aires from a shortage of water similar to that produced in '37, has prompted study for determination of the effect that the settling of suspended matter during three or four days would have upon the efficiency of the present system of coagulation. Results of this study showed that: (1) with the same dose, the time for the appearance of the floc is less in the raw water than the settled water; (2) size of floc was same in both raw and settled water; (3) same size floc with same speed of formation could be obtained with less coagulant for the raw water; (4) turbidity observed one hour after coagulation was usually less in the pre-settled than the raw water when using the optimum coagulant dose; (5) the best coagulant doses were equal or a little less for the settled water. Curves showing the results of two series of experiments indicate that less coagulant is needed to obtain a water of equal turbidity after an hour settling with the pre-settled than with the raw water.—*J. M. Sanchis.*

The Coagulation Process Developed by Dr. Trelles. D. J. BENGOLEA AND A. G. POCCARD. Bol. Obras Sanitarias Nacion (Buenos Aires) **2:** 394 (Apr. '38). The authors describe a series of laboratory experiments designed to determine the effect of the various factors involved in the coagulation of La Plata River water by means of a small dose of aluminum sulfate followed after a short interval of time by one of an iron salt (Trelles process), and to compare the efficiency of this process with that of other schemes of water clarification. The turbidity of the raw water varied from 70 to 500 p.p.m., color between 12 and 30 p.p.m. alkalinity as $CaCO_3$ between 25 and 70 parts p.p.m. and pH between 7.1 and 8.2. The criteria used to determine the efficiency of the coagulation process was the turbidity and the color remaining in the treated water after after 45 min. sedimentation. Best results were obtained with a time interval of 90 seconds between the addition of chemicals, dispersing the coagulants at 250 r.p.m. during 10 seconds and flocculating during 4 min. at

70 r.p.m. Most satisfactory proportion of coagulants was two-thirds of total dose alum and one-third of iron salt. Practically no difference in the results obtained when ferric sulfate, ferric chloride, or chlorinated copperas were used in combination with aluminum sulfate. Experiments showed the Trelles process superior to those using aluminum sulfate alone either in single doses or fractionated. Studies also made to determine the effect of: (a) mixing the aluminum sulfate and iron salt before adding them as well as using a split dose of the combined chemicals; (b) addition of both chemicals to the water at the same time; (c) adding the iron salt before the aluminum sulfate using the same proportions used in the other experiments, that is one-third iron salt and two-thirds alum; (d) adding the iron salt in proportion of two-thirds to one-third of alum; (e) fractionating the dose into three and four parts with one min. interval between the addition of each fraction. All these experiments gave poor results as compared with those obtained by the Trelles process.—*J. M. Sanchis.*

The Clarification of Loire Waters. O. DUDEVANT, E. LASAUSSE AND L. FROCRAIN. Ann. Hyg. publ. (Paris) **16:** 149 ('38). Describes experiments in the laboratory and on a plant scale at the La Roche water works, Nantes, on the addition of aluminum sulfate and ferric chloride to water from the Loire. Effects of calcium, silica and colloids in the water, and of pH value and agitation on the rate of coagulation and sedimentation were examined. If flocculation is too slow floc is carried over to the filter which rapidly becomes choked. Treatment with aluminum sulfate did not render the water more liable to attack lead. The dose of ferric chloride required (12–50 grams per c.m.) was much more variable than that of aluminum sulfate; the latter is relatively high (40–50 grams per c.m.) whether the river is in flood or not. Ferric chloride does not choke sand filters as rapidly as aluminum sulfate does. Though ferric chloride is relatively expensive its price would be reduced if its use as a coagulating agent increased.—*W. P. R.*

How Watertown, S. D. Reduced Coagulant Demand With Bentonite. R. E. DRISCOLL, JR. Pub. Wks. **70:** 1: 15 (Jan. '39). Use of volclay, a Black Hills high-swelling colloidal bentonite, in 1.4 m.g.d. water purification plant of Watertown, S. D., reduced chemical costs approx. $6 per day. Water from Lake Kampeska is flashy in summer with turbidity ranges of 30–200 p.p.m. (caused largely by wind action); av. alk.—197 p.p.m., free CO_2—16, total hdnss.—252 and pH—7.6 to 8.4. Dose chemicals used, bentonite 1.5 g.p.g. and alum 0.25 g.p.g.; bentonite thoroughly immersed in dry-feed solution pot and in auxillary barrel, alum soln. added to this suspension. Results obtained satisfactory.—*Martin E. Flentje.*

Coagulation. Part IV. Effect of the Concentration of Alkaline Carbonates and Neutral Salts. J. R. BAYLIS. W. W. and Sew. **84:** 426 (Nov. '37). Study necessitated by variance between coagulation tests on "synthetic" and "natural" waters. Tests on synthetic waters using $Al_2(SO_4)_3$ as coagulant are described and presented in graphic and tabular form. These show that, with pH 7.0, the coagulating time decreases as $CaCO_3$ is increased up, to about

75 p.p.m., but above this point, coagulating time increases. For constant alkalinity, pH has strong effect on coagulating time, minimum time being required at pH 7.2. Shortest coagulating time, at pH 7.0, for $MgCO_3$ alkalinity, is between 75 and 100 p.p.m. alkalinity. Na_2CO_3 alkalinity gave similar results. Wide pH range of good coagulation of rain water sample with added $CaCO_3$ was believed caused by presence of Si. With Lake Michigan water, rapid coagulation was obtained in pH range 5.6–7.4. Concentration of $CaSO_4$ within reasonable limits has little effect on coagulation with $Al_2(SO_4)_3$. Up to 100 p.p.m., sulfates of Na, Mg, and NH_4 have little effect on coagulation. Effect of NaCl seems nil.—*H. E. Hudson, Jr.*

On Coagulants, Especially the Use of Sodium Aluminate for Water Purification. Ludwig Werner Haase. Gesundheits-Ing. **61**: 610 (Oct. 15, '38). The general properties of coagulants are described and their effect is attributed more to mechanical adsorption properties than to flocculation of colloids of opposite charge. As reasons for this belief are mentioned: Positively as well as negatively charged particles are eliminated; the majority of waters can be cleared on the acid as well as on the alkaline side of the so called isoelectric point. Adsorption can be aided or hindered by flocculation, but is more influenced by temperature and pH which regulate the swelling or shrinking of the floc. As disadvantages of alum are mentioned the reduction in carbonates and the careful control of pH required to get highest insolubility of the aluminum hydroxide and highest swelling of the floc. After clarification such water requires deacidification. These disadvantages avoided by use of sodium aluminate, AlO(ONa), in which the aluminum hydroxide has acid properties, forming an alkaline salt with sodium hydroxide. A long review with bibliography is given on use of sodium aluminate. Present observations do not allow full explanation of the results obtained. Data on investigations by the author on use of sodium aluminate are given which can be summarized as follows: Whereas the treatment of drinking water required 10 to 20 p.p.m. of alum, it was sufficient to use only 2 to 5 p.p.m. of sodium aluminate. Thorough mixing necessary. Soft waters, water with free CO_2 and water containing manganese require an alkaline filter; for hard water a silica sand filter is sufficient. Floc settles out in the top layer of the filter and is easily washed out. Photoelectric measurements show that the water is as clear as distilled water, yet slightly more greenish. Bacterial reduction is fully satisfactory. Iron and manganese are completely removed, also silica. Calcium is removed to a slight extent, whereas no change in the magnesium content was observed. Water for swimming pools can stand a higher chlorination without producing chlorine odors or disturbances to the swimmers, or a lowering of the pH, as the sodium neutralizes the hydrochloric acid formed. As a precipitant in sewage sodium aluminate has advantages due to its alkaline properties.—*Max Suter.*

Results from the Use of Silicate as a Coagulation Aid. A. R. Todd. W. W. and Sew. **85**: 1108 (Dec. '38). At Wheeling, W. Va., floods cause turbidity rise and mineral content decrease. Such conditions are accompanied by weak coagulation. Trial of addition of sodium silicate to make up flood-time de-

ficiency in silica was astonishingly successful. Settled water prior to silicate treatment had 25 turbidity; during silicate application, settled turbidity was less than 1.—*H. E. Hudson, Jr.*

"Chlorinated-Copperas". F. O. Baldwin. W. W. and Sew. **85:** 197 (Mar. '38). Results from fresh chlorinated copperas solutions are not comparable to results from "stale" solution. This paper describes laboratory procedure for frequent preparation of fresh solution.—*H. E. Hudson, Jr.*

New Process for the Manufacture of Aluminum Sulfate. Eduardo D. Garcia. Bol. Obras Sanitarias Nacion (Buenos Aires) **1:** 53 (Jul. '37). Study of processes generally used for manufacture of aluminum sulfate has led to the following conclusions: (1) If the acid employed is weak (40° Baumé), it is necessary to use a large amount of auxiliary heat. (2) If the acid is strong and if no agitation is used, the yield is poor. (3) Use of dilute acid prolongs the time necessary to obtain the finished product. (4) Use of steam for indirect heating, when fairly dilute acid is used, involves installation of coils with consequent inconvenience and expense. (5) Spraying atomized water to slow down the reaction, results in much of the aluminum remaining unattacked. (6) Slow feeding of the bauxite (between 30 and 45 min. even for small batches of 5 tons) requires vigorous agitation to prevent curdling. In order to avoid most of these uneconomic features, author has devised, and patented, the following procedure: The bauxite is ground to a fine powder and mixed gradually with sufficient water to give a suspension of approx. 18% usable oxides of aluminum and iron. This mixture, which is kept homogenized by blowing air through it, is discharged into a reaction tank which is also equipped with air jets for stirring. Sulfuric acid is then added slowly and in such form and quantity that when mixed with the water present it will attain an approx. density of 51° Baumé at 15°C. In order to utilize fully the heat generated by the reaction, it is recommended that the amount of acid required be added continuously in about 4 min. The reaction is considered completed when one-half as much time as was required for the addition of the acid has elapsed. Air may be injected continuously or intermittently during reaction. Trial runs in 60 cu. meter tanks indicate that the new method will produce about 500 kg. per hr. per cu. meter of tank capacity or from 4.6 to 18 times as much as produced by any of the four better known processes now in use.—*J. M. Sanchis.*

A New Type of Meter for the Determination of Sedimentation. Jar. Milbauer. Zeit. analyt. chemie **103:** 419 ('35). This meter consists of a vertical glass cell 60 cm. (24") high and with an inside opening 6 x 6 cm. Two opposite sides are made of polished plate glass 4 mm. thick. The other two sides of common glass are covered with black paper. The measurements of turbidity are made by an apparatus that can be moved along the plate glass side and that contains on one side a source of light with a thermo filter and a small slot. Opposite is also a slot and a photoelectric cell. The process of sedimentation can be followed by measuring at regular intervals the amount of light passing through the cell at various depths.—*Max Suter.*

Size Analysis by Photographic Sedimentation. W. F. Carey and C. J. Stairmand. Paper presented to the Inst. of Chem. Engrs. Mar. 8, '38; Industr. Chem. chem. Mfr. **14:** 141 ('38). An illustrated description of the design and operation of apparatus for analyzing sizes of particles in the range 1μ–100μ. The tracks of particles are photographed as they fall in a stagnant liquid under the action of gravity. The distance through which each particle falls in a given time is measured; the diameter of the equivalent sphere can then be calculated.—*W. P. R.*

A New Installation for Elimination of Dust in Lime Feeders. Willi Walther. Gas-u. Wasser. **81:** 469 (Jun. 18, '38). Lime dust is very detrimental to health of workers causing drying of lips and inflammation of eyes and nose. In Frankfurt A.M., where hydrated lime is used for deacidification of the water, a lime feeder was designed that evacuates all lime dust and cleans the air before discharging it. Sacks are opened and emptied on a sloping channel over which a hood connects to the suction pipe. Only dusty air formed is pulled away. Main body of lime passes under a hinged hanging plate into the mixing tank. Dusty air passes through a vertical cylinder divided by a vertical plate into two compartments to force the dust down on one side and then up on the other. In the bottom are water sprays which eliminate all dust from the air.—*Max Suter.*

New Sanitary Unit Simplifies Treatment and Cuts Construction Cost. Anon. Eng. Cont. Rec. **51:** 27: 13 (Jul. 6, '38). New type of unit for performing in single tank the 2 basic steps of pre-flocculation and sedimentation has been introduced recently by Dorr Co. Unit, which is applicable to water, sewage and trade waste treatment, is combination of Dorrco flocculator and advanced design of square sedimentation unit designated the Dorr Squarex clarifier. Special mechanism sweeps entire floor area of square tank. Savings in construction cost when multiple units are employed, permitting use of common walls. Furthermore, dividing wall between clarifier and flocculator compartments need not be of cantilever construction since liquid is always present on both sides. Clarifiers furnished in standard sizes from 20 to 100 ft. square: dimensions of flocculator compartment varied to comply with local detention period requirements.—*R. E. Thompson.*

Performance of Mixing Equipment. R. C. Gunness and J. G. Baker. Ind. Eng. Chem., **30:** 497 (May '38). Mixing equipment may be tested to establish optimum conditions for installation already in service or to detn. optimum design of equipment for proposed installation. Tests to be made also depend on material being mixed. In designing, translation of test data to actual installation may be difficult. Agitation intensity is fundamental in mixing operations but direct methods of approach are lacking because of complexity of turbulent forces involved. Indirect test methods previously used include rate of solution of crystals, increase in conductivity when electrolytic conductor is mixed with water, particle suspending capacity, corrosive attack on soft metals, optical methods in transparent systems, high speed photographic studies, and detn. of fraction of applied power actually available for

agitation. Tests on installed equipment normally yield results readily interpreted on economic basis, i.e., best method of achieving desired result with equipment at hand. For proposed installation, agitation capacity, labor requirement, power consumption, initial cost, maintenance and other factors must be considered. Interpretation of test results is difficult because of lack of standards for judging satisfactory operation of mixing equipment. Proposed indices of agitation have been suggested for use with suspension method of testing (a) min. speed required to reach limiting value for max. sand suspension and (b) ratio of av. sand or liquid concn. at several points in the vessel to concn. with perfect distribution. Detn. of optimum design depends on experimental study of several variables. Use of principles of dimensional analysis is indicated. Further quantitative studies are needed based on standard testing method and results should be expressed in terms of an accepted index of agitation intensity. This should lead to more rational design and utilization of mixing equipment ★[See also other articles on mixing which accompany the foregoing reference]★.—*Selma Gottlieb.*

SOFTENING

Some New Practices in Water Softening. Charles H. Spaulding. W. W. and Sew. **85**: 153 (Mar. '38). The pioneer lime softening plant at Oberlin, O., brought the first practical developments in water softening but overlooked the value of prolonged mixing and utilization of sludge in the softening process. Springfield, Ill., has adapted both to aid in the purification process by means of "precipitators." A precipitator is a circular tank containing an inverted conical mechanical mixing compartment surrounded by settling space. Flow is radial, and is forced to pass through a blanket of sludge at the juncture of the compartments. Contact of water with sludge blanket brings about automatic chemical balance. Capacity of precipitator units increases with rising water temperature, due to reduction in water viscosity. No recarbonation seems necessary and effluent is slightly encrustant. Hardness reduced from 160 to 90 p.p.m. In starting process, pH drop in distribution system necessitated maintaining pH 9.8 in plant effluent. Lime dose has averaged 74.6 p.p.m.; chemical cost—$4.36 per mil. gal. Sludge removal is continuous from precipitators, and sludge is lagooned. Springfield filters rated at 4 g.p.m. per sq. ft., and have been operated satisfactorily at 5 gal. rate. Sand grains are encrusted to more than 1.0 mm. diameter. It is felt that "scaled" sand is useful in bringing the water to chemical balance. Filter cleansing accomplished by means of preliminary jetting with high pressure hose stream, followed by backwash—2 min. at low rate and 2 min. at 45" velocity, and then a short period of low velocity again.—*H. E. Hudson Jr.*

Water Softening Plant Design. Discussion. Proc. A. S. C. E. **64**: 1475 (Sep. '38). (*See* J. A. W. W. A. **30**: 1744 (Oct. '38) *for abstract of original paper by* W. H. Knox). Philip Burgess: That feature of water softening, as well as of a modern rapid sand filter plant which has been least appreciated is the necessity for proper mixing of chemicals after their application with the raw water. Filters designed for filtering softened water should be equipped with devices for high rate washing. The disposal of sludge is the unsolved

problem in connection with the operation of lime softeners. A. ELLIOTT KIMBERLEY: Effective softening and the economic use of softening agents at lime-soda plants are dependent on proper mixing at non-depositing velocities, generally obtained by use of mechanical devices, assisted by a certain percentage of sludge return. A new type of zeolite has recently been introduced which produces carbonic, sulfuric or hydrochloric acid depending on composition of the raw water. Its proper use has the advantage that the quantity of carbon dioxide produced is constant and no phenols or other objectionable materials are introduced into the water. L. R. HOWSON: One half the municipal water softening plants are in Ohio, a state in which it has paid large economic dividends. In one case red-water troubles, resulting from aeration by an inspirator, were overcome by substitution of a simple, splash type aerator. In general, mechanical mixing devices must be used for softening and the mixing period must be relatively long. Sludge disposal from the lime-soda process has not been satisfactorily solved. Filtration rates as high as 3 g.p.m. per sq. ft. are commonly used in softening plants treating well water. CHARLES P. HOOVER: Water-softening plants, it is believed, can be made to eliminate distribution troubles but not the encrustation of filter sand and, at the same time, produce water of the desired alkalinity. Low-alkalinity water containing all, or nearly all, normal carbonates is more corrosive to galvanized metal than water containing no normal carbonates. Four important mistakes to be avoided in softening plant design include: (1) provision for preliminary removal of settleable matter from muddy raw water, (2) avoidance of pressure filters for filtering lime-softened water, (3) provision of accurate chemical feed devices, and (4) avoidance of pipe and concrete sweating in summer weather. M. H. KLEGERMAN: Preliminary testing is more readily possible in the field of water supply conditioning than in many other fields of engineering design. This is exemplified by the writer's experience in a southern municipality. Most conditions involving mixing of chemicals with water for coagulation warrant provision of variable speed devices, particularly in view of the changing characteristics of the water in many instances. ROLLIN F. MACDOWELL: Despite author's statement to the contrary it is practicable to soften water containing more than 800 p.p.m. of hardness, as is now being done at Elmore, Ohio. Patented aerators unnecessary. Where the sludge disposal problem is burdensome zeolite softening should be resorted to. Because of the highly corrosive nature of salt brine used in zeolite plants special attention must be paid to materials used for troughs and piping. The wet salt storage basin should be large enough to store a car load of salt, and brine pumps should be brass lined and mounted. D. E. DAVIS: When dealing with a pure, clean, but hard water a zeolite plant offers many advantages, including low first cost and "fool-proofness" in operation. The choice of type of softening plant for a given situation can only be determined after a careful examination and weighing of the determining factors.—*H. E. Babbitt.*

Typical Costs of Softening Water in the Central West. F. M. VEATCH. W. W. Eng. **91**: 1210 (Sep. 14, '38). Eighty-eight of the 152 softening plants in U. S. in '30 were in central part of country. Costs of treatment vary with

degree of other treatment req'd and character and amount of hardness present. At Carthage, Mo., satisfactory ground water softened in $100,000 plant at chemical cost of $9.52 per mil. gal. and total cost $33.85; same figures for Neodesha, Kan. on turbid polluted water,—$80,000, $10.30 and $52.10. Costs of removing 1 p.p.m. hardness per mil. gal. in 5 plants vary from $0.055 to $0.065 on raw hardness of 248 to 356 p.p.m. softening to approx. 90 p.p.m. in all cases.—*Martin E. Flentje.*

Threshold Treatment. C. P. Hoover and Owen Rice. W. W. and Sew. **86**: 10 (Jan. '39). So-called "threshold treatment" consists of addition of sodium hexametaphosphate to water. Presence of this substance in 2 p.p.m. concentration is shown to prevent deposition of $CaCO_3$. Extended trials in industrial supplies as well as on Delaware and Mt. Sterling, Ohio, municipal supplies confirm this. Plant results at Delaware, where softening is used, show almost complete precipitation prevention, thus preventing water main scaling. The hexametaphosphate also is shown experimentally to have the same effect on heated waters, greatly reducing scaling of hot water heaters, etc. Treatment may be useful in eliminating need for recarbonation where excess lime treatment is not used. ★[No explanation is advanced for the choice of designation: "threshold treatment," which the abstractor regards as a confusing misnomer.]★—*H. E. Hudson, Jr.*

Stabilization of Lime-Softened Water. H. O. Hartung. W. W. and Sew. **86**: 56 (Feb. '39). The St. Louis (Mo.) County Water Company recarbonates with scrubbed stack gases. Approx. 40% of the CO_2 lost in scrubbing and through incomplete absorption in the carbonation basin. 3.6 p.p.m. of carbonates are converted to bicarbonates per gal. of oil burned per mil. gal. Daily carbonate stability tests determine the carbonation treatment. Procedure for making these tests described. ★[McLaughlin's method with some excellent mechanical modifications.]★ Tests using calcium carbonate were made on hexametaphosphate (h.m.p.) stabilized waters. These showed excellent stabilization with one p.p.m. sodium h.m.p. at temperatures up to 200°F. Stabilization was not complete when temperature reached the boiling point and was negligible at 250°F. Combination re-carbonation and h.m.p. treatment were not valuable at high temperatures. Cost of h.m.p. treatment about equal to re-carbonation at St. Louis County, though convenience of former is greater. Former enables coagulation at any pH. Tests made on tetra-sodium-pyrophosphate and these results were as good as those from h.m.p. except for high calcium concentration.—*H. E. Hudson, Jr.*

Experimental Decarbonization of Waters from a Mill Race on the Svitava River According to Zentner Method. F. Kopecký. Plyn a Voda **5**: 15 ('38); Listy Cukrovar (Prague) **56**: 351 ('38). A water predominantly bicarbonate (total hardness 12°, temporary hardness 10°) when treated with lime at 20° required 3–6 hrs. for sedimentation. When the raw water was agitated with lime and with finely ground marble (0.02 mg. per particle) the sedimentation time was reduced to as low as 2 min. The presence of org. substance did not interfere with the sedimentation. Instead of the previous, slowly settling

slime the sediment was an evenly grained sand which can be used for building purposes or as a filtering medium.—*C. A.*

New Water-Softening Plant at Daytona Beach, Florida. A. P. Black and R. G. Hicklin. Am. City. **53**: 4: 61 (Apr. '38). Daytona Beach has long recognized value of soft water and consequently when PWA funds became available, this city was soon in the midst of building a new and modern water softening plant adequate for its needs. Under the old scheme, the city was served by two plants. The new one combines water purification service in one plant effecting a saving sufficient to amortize the cost of the new plant. In addition to the water softening plant consisting of aerators, mixing chamber, clarifier, settling basin, recarbonation chamber and filters, the project included new well supply from 10 wells, raw water pumping station, force main to the new plant and other essential accessories. Water from the new wells averages about 232 p.p.m. of carbonate hardness, 42 p.p.m. of non-carbonate hardness, 10 p.p.m. of sulfates and 120 p.p.m. of chlorides. Testing individual wells indicated wisdom of cutting down the draught and hence the old well system was again brought into use by drawing 40% of the water from it. Lime for softening and alum for coagulation are used. Excess lime is not used because it is desired to dissolve the incrustations from the existing mains to a point where only a thin protective layer will be left. Filter runs are averaging 48 hrs. and wash water is $1\frac{3}{4}$%. Hardness of finished water varies from 88–95 p.p.m. and chemical cost $13.30 per mil. gal. An experienced chemist in a well equipped laboratory controls the plant operation.—*Arthur P. Miller.*

St. Augustine Completes New Softening Plant. A. P. Black and Chas. H. Starling. Pub. Wks. **69**: 5: 15 (May, '38); *also* Am. City **53**: 9: 69 (Sep. '38). $95,000 loan and $77,000 grant from PWA financed municipal 2 m.g.d. softening and purification plant embodying aeration, lime softening, primary clarification, secondary coagulation, settling, recarbonation, filtration and stablization. Supply derived from 8 existing 12" gravel-wall wells along low ridge about 2 mi. SW of city and 3 new 90' deep, 24" gravel wall wells at same location. Raw water has hardness av. 21 g.p.g. 2 grains being incrustant hardness, low Mg content, SO_4 and Cl av. 30 and 44 p.p.m. respectively, Fe high varying from 2 to 3 p.p.m. and with organic color from 50 to 100. Water first aerated, followed by softening with 13 g.p.g. unslaked lime, mixing for 30 min. and 3 hr. settling in clarifier. 3.5 grains alum then added and floc conditioned for 20 min., settled, filtered and stabilized with 1 g.p.g. soda ash to maintain pH 8.6-9.0, slightly above equilibrium point. Finished water hardness 65–75 p.p.m., cost of treatment for chemicals has av.'d $15.72 per mil. gal. Improvement in water quality has resulted in 25% to 30% increase in consumption.—*Martin E. Flentje.*

Burlington Builds Large Capacity Water Treating Plant at Galesburg, Ill. Anon. Ry. Age **104**: 835 ('38). The Chicago, Burlington and Quincy R. R. recently completed installation of water softening plant at their Galesburg, Ill. terminal, having rated capacity of 2 m.g.d. using lime, soda ash, and

copperas. Water obtained from their Bracken reservoir of 900 mil. gal. capacity, built in '23 about 6.5 mi. south of Galesburg. Total hardness will av. 23.5 g.p.g. of which 6.0 is non-carbonate and 17.5 carbonate. Unusual features in this installation are the duplicate 38.5′ dia. by 40′ high steel settling tanks each of which has an external 10′ dia. by 40′ high reaction tank in which are partitions to force the water and chemicals from top to bottom of tank three times before going to bottom of settling tanks through 36″ downcomers. Chemical treating equipment also in duplicate and housed in a substantial brick building. General plan given showing the arrangement of equipment. Chemical proportioning controlled by valve actuated by float in raw water weir box at top of settling tanks.—*R. C. Bardwell.*

Water Softening Plant at Newnham Pumping Station. ANON. The Engr. (Br.) **166**: 480 (Oct. 28, '38). Ground water taken at depth of 350′ from wells in limestone shows carbonate hardness of 24.2 p.p.m. and sulfate hardness of 3.2. Water is otherwise pure, softening only being required. Preliminary tests indicated high porosity of the overlying chalk stratum precluding discharge onto ground surface of waste water from regeneration of a base-exchange softener. Lime process of softening was, therefore, chosen. Recovery of precipitated calcium carbonate was planned for commercial value and precautions were taken in the plant design to protect purity of this by-product. Installation designed to provide 40,000 gal. (Imp.) per hr. with easy extension to double capac. Lime water used as reagent, because of impurities normally found in milk of lime. Only a portion of the water treated, remainder being by-passed around the plant to be mixed with the softened and filtered plant effluent. Softening plant consists of two basins built above ground, with a tower between them containing lime saturators and chemical dosing equipment. Basins are of same size and design, conical, with straight portion at top, 40′ diam. by 30′ deep. Softened water passes from the softening basin to the coagulating basin, and thence to the filters. Ferric chloride used as coagulant. Three horizontal filter units, each 8′ diam. Filters washed every 100 hrs., although this is probably twice as often as needed. Effluent sterilized with chloramine and then mixed with untreated water in the common delivery pipe to storage reservoir.—*H. E. Babbitt.*

Organolites. Organic Base-Exchange Materials. HARRY BURRELL. Ind. Eng. Chem. **30**: 358 (Mar. '38). Suggestion is made that organic counter parts of zeolites be called "organolites." Base exchange properties of organic or humus constituents of soil are well known, and lignite or brown coal beds have been tried abroad for water softening. However base exchange capacity is low and treated water is colored. Synthetic product patented by Adams and Holmes is prepd. from polyhydric alcohols and formaldehyde. Present authors worked with products made from initially water soluble wood extracts, especially of tannin type. Tannin-formaldehyde resins using various sources of tannin softened 0 to 700 cc. of water of 400 p.p.m. hardness passed through 10 cm. x 1 cm. diam. column of 20 to 40 mesh organolite. Using sulfited quebracho extract (Q) as tannin source, active resins were also obtd. with acetaldehyde and with acetone. More active prepns. were obtd. by rendering

soluble wood ext. insoluble by acid treatment. Product contains groups such as hydroxyl or sulfonic capable of salt formation, and usable directly or by conversion to sodium salt with NaCl. Product was prepd. from (Q), e.g., by pouring into 3 times its wt. of concd. H_2SO_4, allowing to react at 80°C. for 30 min., pouring into large vol. of water, drying at 110°C., grinding, and regenerating 10 cm. x 1 cm. diam. column with 200 cc. of 10% NaCl. When tested as above, it softened 1650 cc. of water. Product prepd. from Bindex, a commercial dried hemlock cellulose sulfite liquor, had capacity of 1300 cc.; active prepns. also obtd. from other wood tannins. Nearly 100% greater yield of product of equal or greater capacity can be obtd. by substituting acid-sludge by-product from petroleum refining for H_2SO_4 in treatment of (Q), Bindex or chestnut ext. For some purposes acids may be used instead of NaCl for regenerating organolites, yielding effluent contg. acids corresponding to anions of raw water. In waters with bicarbonate hardness, effluent contns. carbonic acid, readily removable before boiler use, thus decreasing total solids; or free CO_2 in water may be used to recarbonate effluent from lime softening process. If sulfate is also present, H_2SO_4 must be neutralized, possibly by anion-exchanging resins of Adams and Holmes. Amount of hardness removed per lb. of salt used in regenerating was greater for (Q)-acid sludge and Bindex-acid sludge than for (Q)-formaldehyde or greensand. Capacity of organolites is less sensitive to pH changes than that of zeolites; it is practically unchanged between pH 4.0 and 7.0, above and below this range, capacity increases with increasing pH. Decrease in capacity from pH 11 to 2 is 33%. No tendency to disintegrate, dissolve or throw color occurs throughout range. (Q)-H_2SO_4, (Q)-acid sludge and Bindex-acid sludge did not color distd. water after 6 days contact, but chestnut-H_2SO_4 and (Q)-formaldehyde did. Last named also showed mold growth not capable of growing on other organolites when inoculated. Density of dry organolites is 40 to 45 lb. per cu. ft. compared to 45 to 50 for gel zeolite and 80 to 90 for greensand. Possible defect of organolites is low physical strength when wet. Work has not progressed beyond experimental stage but evidence indicates that organolites may find application in water softening and acid regeneration.—*Selma Gottlieb.*

Alkali Adsorption by Synthetic Resins. E. I. AKEROYD AND G. BROUGHTON. J. phys. Chem. **42**: 343 ('38). Describes investigation made to elucidate the mechanism of the process of adsorption by phenol-formaldehyde resins and the relation of the molecular structure of the resins to their adsorptive power. The total adsorption and rates of adsorption of calcium hydroxide and of barium, sodium, and trimethylbenzylammonium hydroxides by simple mono-, di-, and tri-hydroxy phenol-formaldehyde resins were measured. Results, which are given and discussed, may be explained on the basis of chemical reaction of the calcium or other hydroxide with phenolic hydroxyl groups of various degrees of accessibility rather than as a pure adsorption phenomenon. The accessibility of the phenolic hydroxyl groups, as shown by the amount of base adsorbed, depends on the structure of the phenol concerned and on the degree of polymerisation of the resin. The authors consider that the results should be of value in the study of resins made from more complex naturally occurring phenols which are of greater utility in commercial water softening. —*W. P. R.*

Water Softening with French Zeolites. V. Charrin. L'Eau **31**: 105 (Sep. '38). Disadvantages of hard water for domestic and industrial uses, and nature and sources of hardness in water are discussed. A great part of France is calcareous; in the Paris district some waters have 350 to 400 p.p.m. total hardness, in the lower Rhone 280 to 300 p.p.m., and in the plains of Languedoc sometimes up to 700 p.p.m. In zeolite softening, hardness falls to zero and softening system is simple in construction. Consumption of salt is 2 to 2½ grams per gram of hardness removed. Salt costs 230 to 240 francs per metric ton at destination. In France zeolite softening has not been largely developed to date because of high cost of either natural or synthetic material, but manufacture of an excellent synthetic zeolite has just been begun near Marseilles, where bauxite is abundant, and development of water softening should now be facilitated, depending on economic conditions.—*Selma Gottlieb.*

Hydrogen Exchange Materials. I. G. Farbenindustrie A.-G. F. P. 817,881. Chem. Zbl. **1**: 961 ('38). Hydrogen-exchange materials which can exchange their hydrogen for metal ions and are especially suitable for combining with basic substances present in solution and for freeing acids from their salts consist of a carbonaceous material, such as anthracite, coal, brown coal, peat, wood, etc. which has received thermal treatment. Thus brown coal is heated in the form of briquettes for 1–2 hours in a closed furnace at 200–400°. Carbon dioxide may be introduced if necessary to prevent ignition of the mass. The heating is effected at about the temperature at which the mass begins to distil.—*W. P. R.*

Imparting Ion-Exchange Capacity to Coal. Reginald Furness and Joseph Crosfield & Sons Ltd. Brit. Pat. 486,471. Jun. 3, '38. The coal is subjected to action of fuming H_2SO_4 or SO_3 dissolved in liquid SO_2 until the reaction product shows desired degree of ion-exchange capacity, the solvent and unreacted acid then being removed. Product is suitable for water-softening.—*C. A.*